SPATIAL RESILIENCE AND THE INCORPORATION OF TRADITIONAL ECOLOGICAL KNOWLEDGE IN MAPPING SITKA HERRING

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Abstract

This project assesses the utility of Traditional Ecological Knowledge (TEK) in conducting research on herring stocks within Sitka Sound. By considering ethnographic data of the marine environment it is possible to identify key spatial attributes associated with the resource. This information was used to construct a social-ecological systems model (SES) for analysis within a spatial resilience framework. From this SES model, resilience surrogates were identified to analyze effort and success within the fishery. These indicators provided valuable insight into how subsistence users relate to the marine environment when they participate in the harvesting of herring spawn. To collect TEK data, the researcher, employed as a graduate intern with the Division of Subsistence, Alaska Department of Fish and Game (ADF&G) worked cooperatively with the Sitka Tribe of Alaska (STA). TEK data was used to identify marine habitat types, subsistence harvest locations (mapping), customary and traditional practices, and changing trends in accessibility to the resource. This information was supplemented with quantitative data including spatial habitat mapping and herring spawn distribution. A Geographic Information System (GIS) was used to display, analyze, and understand these variables and their measured outcomes to construct the SES model.

Dedication

This thesis is dedicated to my father, Warren Shewmake. Thank you for instilling in me a love of fishing, an appreciation for the social - ecological realms in which fishing takes place, and for encouraging my scientific curiosity.

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Introduction

An Introduction to the Research

In recent years, the Sitka Sound Herring stock has received increased attention from commercial fishermen, subsistence harvesters, and fisheries policy makers. Recent increases to the guideline harvest levels (GHL) for the commercial fishery indicate a growing stock for a fishery that had in the past been nearly depleted. With the successful recovery of the stock a host of new challenges have come to light for fisheries managers and policy makers to tackle. These challenges go beyond managing the stock itself and expand into the realm of managing people and personalities associated with the resource.

As fishing efforts increase and the economic value of the fishery rises, so too have conflicts over use and allocation. Much of this conflict has occurred between two user groups, subsistence herring egg harvesters and commercial sac roe fishermen. As the table shows, the total number of proposals addressing conflicts between subsistence and commercial access has tripled in the past 6 years. But as the total number of Southeast herring proposals has declined, proposals related to this conflict now represent over a quarter of the herring proposals discussed. During the 2009 Alaska Board of Fisheries (BOF) Southeast Finfish Meeting, held in Sitka, nearly 300 members of the public signed up to testify, with the vast majority of them addressing herring issues in Sitka (Board Support correspondence). Public presence at the 2012 meeting, held in Ketchikan, was not quite as overwhelming yet Sitka herring was still a dominant focal point of testimony and debate. Several of these proposals were submitted by various user groups associated with the Sitka Sound herring stock and were attempts to remedy perceived problems with the management of the resource (ADF&G BOF Proposal Index, 2012). This situation puts Alaska Department of Fish and Game (ADF&G) in the difficult position of trying to manage the resource in a way that upholds the State of Alaska's constitutional mandate to manage the resource "for maximum use consistent with the public interest" while adhering to principals of "best available science" and "sustained yield" (ADF&G Website, 2012).

The cultural norms and values that are the underlying basis for creating and defending these proposals highlights the importance of access to the resource by both groups, the need for better social science tools for making management decisions, and the role of space as a guiding or limiting factor in this complex system. By analyzing and understanding these norms and values and relating them to the marine space in which they occur, fisheries managers and policy makers can potentially have access to a new set of management tools useful in mitigating future conflicts.

Research Questions and Objectives

This project will attempt to answer the following research questions:

1. What norms and values of the herring stock are imbedded in Traditional Ecological Knowledge (TEK) and what do they say regarding the spatial attributes that comprise subsistence use?
2. Can participatory mapping and Geographic Information Systems) GIS be used to construct a social-ecological system model for identifying resilience surrogates within the subsistence fishery?

3. Does spatial resilience have a useful role in negotiating conflicts regarding access to Sitka Sound Herring and a broader significance to fisheries management in general?

From these research questions, this project will seek to address three primary objectives. They are:

1. *To identify, through TEK, social and ecological attributes that drive subsistence harvest effort and understand how these variables are connected to the geographic space in which the fishery occurs.* (Ch. 1)
2. *To map and analyze the social-ecological system that includes pacific herring and subsistence use.* (Ch. 2)
3. *To situate recent policy debates and conflicts over resource management within the broader theoretical framework of spatial resilience.* (Ch. 3 and Ch. 4)

Literature Review

Incorporating TEK: Opportunities and Challenges

Berkes et al. (2000) provides a good working definition of Traditional Ecological Knowledge (TEK) that serves as an appropriate starting point for critiquing and analyzing its integration in management, science, and policy. They define TEK as:

> A cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationships of living beings (including humans) with one another and with the environment.

TEK played a key role in guiding research for this project. The rationale behind this was that subsistence harvesters rely heavily on transmitted cultural knowledge of herring fisheries and the way in which herring interact with the marine environment to guide decision making processes. This knowledge, in turn, directly influences how harvesters interact with the marine environment by guiding when, where, and how harvest sets are made. Analyzing these norms and values should illuminate the importance of environmental variables such as substrate and vegetation types in harvest site selection as well as in better defining critical use areas. This information is then used in the construction of a social-ecological system.

A social ecological system (SES) is one in which social and biological processes are considered in defining environmental interactions. Linking the social and ecological in a systems approach is an important step in recognizing the transformative power that society has on the landscape and how the landscape reciprocates in shaping society. According to Berkes and Folke (2000), there is no “single, universally accepted way of formulating the linkage between social systems and natural systems”. However, including social systems in a more holistic analytical approach generally focuses on three elements.

The first comes from the critique of the “tragedy of the commons” (Hardin 1968, McKay 1995) and includes *social capital*. This element looks at the way that social, political, and economic organizations (in the form of social institutions) mediate the relationship that people have with environmental services. Here there is a strong overlap with the tools of political ecology, which also developed from common property thinking, cultural ecology, and human geography (Robbins 2004). Simply put, people rarely (if ever) have direct and open access to a resource. There can be many formal and informal rules and structures of power that mediates who gets what, when, and how. In many cases these access rights are formalized in political systems, but not always.

The second social system emphasis comes from political and ecological economic thinking, and centers on *natural capital*. The view here is that resources can be managed sustainably by incorporating value and using economic incentives and institutions to monitor and control the flow of that value (Berkes and Folke 2000). There can be a lot of issues with this approach, including who determines the value, and how to account for non-monetary values, like the cultural importance of a resource.

The last aspect of social system theory, as identified by Berkes and Folke (2000) includes the importance of *cultural capital*. They define cultural capital as the means of connecting *natural capital* to societies in order to create *man-made capital*. In many ways, this element really encompasses the first two into one larger package. Simply understanding social institutions or the value of natural capital isn't enough. These resources sustain livelihoods. Disruptions to ecosystem service have very real social, economic, and cultural impacts on the lives of those who depend on them. In a global economy those impacts also have a domino effect, spiraling outward to a world wide scale.

The social and the ecological are linked through these three elements. Understanding resource access and value are the first steps in determining why these scarce resources require management in the first place. Considering how a change in the access and/or value of an ecosystem service further contextualizes the impacts to livelihoods. Scarcity of inputs alters human outputs and limits productive capacity. Therefore managing resources requires the incorporation of social systems. Ultimately, humans shape the landscape that they inhabit and the resources housed within, and the landscape and resources shape the face of humanity.

In order to link social systems with ecological ones, scientists need tools to document social phenomenon and analyze the role of the social in shaping the ecological, and vice versa. The incorporation of the social dimension requires human context. Ethnography and anthropology provide the tools for developing and framing of that context.

In distinguishing a line between anthropology and ethnography, Tim Ingold (2008) describes the objective of anthropology as a way to seek “critical understanding of human beings and knowing in the one world we all inhabit”. He further describes the role of ethnography as a way to “describe the lives of people other than ourselves, with an accuracy and sensitivity honed by detailed observation and prolonged first-hand experience.” Ingold stresses that the two are similar, compatible, but not necessarily interchangeable concepts. The emphasis in both methods is on what people believe about their environment, how those beliefs were formed and are continually shaped, and how that knowledge impacts decision making process. This is what Berkes et al. (2000) describe as the “knowledge-practice-belief complex” that constitutes the foundation of Traditional Ecological Knowledge (TEK).

Ethnography in particular emphasizes the importance of embedded learning. It relies heavily on tools such as participant observation, semi-structured interviewing, and participatory mapping (to name a few) (Bernard 2011, Huntington 2000). Each of these methods is designed to capture data on the “knowledge-practice-belief complex”. This data provides the basis for developing context. That context can then be expanded through anthropological methods and theories to reconstruct how knowledge and beliefs are formed and maintained and how that impacts every day decision making (Bernard 2011).

Working from Ingold’s (2007) definition of anthropology and ethnography, it’s easy to see the importance of both methods in constructing and analyzing social systems. If the entire point is to understand how humans and the environment shape each other, then studying the people themselves should be a representation of that process. If TEK is acquired through an interactive process with the environment (learning by doing) then researchers must also embed themselves in that learning process, studying the practices that give rise to knowledge and belief (Berkes et al. 2000, Huntington 2000).

Similar methods using TEK to define social ecological systems have been employed by Johannes (1998), Berkes et al. (2000), and Garcia-Quijano (2009). By using TEK to understand the human – environment interaction, the goal is to situate the importance of these areas in a way that is both socially and ecologically significant (Berkes et al. 2000). Spatial analysis techniques were used to complement TEK with quantifiable forms of data that are more easily understood by the scientific and management community-at-large to further demonstrate the importance of these areas and the adaptive knowledge surrounding them. By intertwining TEK with spatial analysis, a more holistic understanding of the SES emerges. Understanding this interdependence is crucial to analyzing how conflicts arise when changes in spatial distribution of herring eggs impact subsistence harvests within the marine landscape. Such disruptions limit access to the resource and create a scarcity in the availability of herring eggs. Thus it is important to understand the role that spatial variability and resilience plays at such times.

Resource Conflicts and the Role of Space

At the core of this research is the idea that conflicts over herring (and the management thereof) aren't simply occurring *within* a given space, but are occurring *because* of constraints and competition caused by the arrangement and distribution of resources across space. This is evidenced by efforts employed in remedying such constraints. Two key proposals that were submitted to the Alaska Board of Fisheries dealt directly with concerns over space and its importance in reliably accessing the resource. Both proposals were publicly generated and were very similar in purpose and scope. Each sought to set aside a "subsistence only" marine protected area that would provide an area of refuge for the herring stock as it approaches spawning maturity. The first proposal was drafted by a Sitka tribal elder with a well established and long standing connection with the subsistence herring fishery. The area focused around a core group of islands well established in Traditional Ecological Knowledge (TEK) as being important refuges for spawning stocks (ADF&G BOF Proposals Index, 2012). Historical data on spawn deposition and subsistence harvest efforts substantiate the vital role this area plays in the annual spawn as well as in providing reliable access to the subsistence fishery. This proposal sought to protect this "Subsistence Only Zone" from commercial harvest effort due to the perception that commercial fishing pressures disrupt the natural spawning process by stressing and scattering the herring school(s). It was argued that a scattered and stressed stock is unpredictable, making it harder for subsistence harvesters to anticipate where fish would spawn and increasing the degree of difficulty for subsistence users trying to maximize harvest effort. By setting aside this "Subsistence Only Zone" the proposer sought to create a safe haven were fish could move unmolested, increasing the certainty that eggs would be deposited in areas that are easily accessible and ideal for high quality harvest (ADF&G BOF Proposals Index 2012). Concerns were raised over the inclusion of a large area of deeper water in this "Subsistence Only Zone". This area has traditionally been used as a staging area for the commercial fleet and an area open to commercial fishing (ADF&G Staff Comments 2012). A second proposal, generated by the Sitka Area Council, sought to reconcile this conflict by redefining the boundary to allow a larger area of deep open water to remain open to fishing and the staging of the commercial fleet (BOF Proposal Index 2012). Through the process of public testimony and Board deliberation, a third proposal took shape that attempted to accommodate and balance the needs of the commercial fleet with subsistence concerns in a manner that wouldn't inhibit ADF&G's ability to manage the fishery. This proposal passed by a majority vote. These proposals and the ensuing policy process highlight the role that geographic space plays in creating and resolving conflicts over this highly valued resource. This further demonstrates the importance of understanding social and cultural norms and values of local subsistence users when trying to understand the policy process and management actions. When dealing with marine protected areas, questions of "protection of what and for/from whom?" are fundamental to understanding management implications (Macinko 2007). The goals of this project are to define the constraints that the marine environment place on subsistence herring harvest, how this is represented through TEK, and the implications of a “subsistence only zone” on spatial resilience. Approaching the problem in this manner illuminates the impact that scarcity has on conflict between users with different cultural backgrounds and objectives for resource use. In this instance, scarcity refers to anything that constrains subsistence activity within the given space. To achieve these goals, this project employed methods of spatial analysis framed within a scientific theory of spatial resilience of complex social-ecological systems. By better understanding this SES within the marine environment, it is possible to dissect the principal components of effort in the subsistence fishery and the conflicts that arise when accessibility is constrained and/or subsistence needs go unmet. A better comprehension of how livelihoods are linked to the environment and how people and herring interact with each other and the ecosystem could potentially lay a foundation for resolving future conflicts over a culturally and economically important marine resource. These methods would not just focus on people or fish, but on the place in which they interact.

Spatial Resilience as a Theoretical Framework for Research

Spatial resilience is a relatively new theoretical framework nested within the broader emerging science of complex systems analysis of social ecological systems (Cumming 2011). It is an interdisciplinary approach to analyzing human-environment interactions. In particular, it emphasizes the way in which spatial variability drives interactions between people and places, both internally and externally to a complex system of interest (Cumming 2011).

When looking at the internal mechanics of a system, spatial resilience theory considers factors such as the size and shape of the system, and whether this is fluid or static over time. It also considers spatial variation within the system as well as any unique properties that may exist. Externally, factors such as context (which includes spatial surroundings outside of the primary scale of study), connectivity (or how external elements are interacting with internal elements), and spatial feedbacks and subsidies are key components to spatial resilience theory (Cumming 2011). There are, however, challenges to applying resilience theory. Operationalizing the resilience framework for use in empirical tests is often difficult. Bennett et al. (2005) developed a simplified systems methodology which allows for the identification of "resilience surrogates" within the social-ecological systems. These surrogates then provide a means for hypothesis testing what factors drive the resilience of a particular system. This methodology was applied to the subsistence herring fishery in Sitka Sound to determine what drives effort and success in harvesting herring eggs for subsistence use. By analyzing spatial resilience, it is possible to understand the mechanisms driving the current state of a complex social-ecological system as well the impacts of alternative states.

Spatial resilience is very applicable to conflicts over pacific herring harvests in Sitka Sound since herring interact with the marine environment in very specific and predictable ways. Forty years of spawn deposition data show that herring spawning effort is centralized around a core group of islands within the Sound itself.   This is the same core islands that the "subsistence only zone" sought to protect. This predictability in the spatial distribution of the herring spawn has allowed the Tlingit of the Sitka area to reliably harvest herring for food and fish oil since time immemorial (Thornton et al. 2010). Because of this, herring have become imbedded in Tlingit culture and knowledge. Today herring continue carry a deep significance in Tlingit life, a fact that is expressed through their Traditional Ecological Knowledge of the resource and their active interest in the management of herring. Similarly, herring predictability has aided commercial fishing efforts, most notably in the herring "reduction" fisheries that took place from 1882 to 1966 (Thornton et al. 2010) and more recently in the Sac Roe Seine fishery.

This emphasis on predictability implies a lack of resilience to major changes in herring stock, behavior, or habitat and the need for a stable state. This means that subsistence harvesters are strongly linked to particular features of the marine landscape and any changes to the landscape, the stock, or how the two interact, could have serious impacts on local culture and livelihoods. This study seeks to show how concerns over scarcity and constraint lead to conflicts over herring, how this impacts the management process, and develop tools that allow managers to mitigate these social aspects.

Summary

Through the use of spatial analysis and GIS, it should be possible to explore the complex interaction of subsistence harvesters and pacific herring within the context of the marine landscape. Because TEK is a social construct, it should contain valuable clues as to what social and ecological variables guide decision making processes as to when and where herring roe is collected. Using these variables in conjunction with quantitative analysis of the marine environment, it should be possible to map and understand the significance of certain areas as customary and traditional harvest areas, and to understand how effort is employed in the fishery. By defining and understanding these linkages to the landscape, an overall picture of spatial resilience of the social-ecological system could be developed that explains the cultural connection to the environment, and how resource conflicts arise when these linkages are disrupted. Managing these conflicts requires dialogue that spans the gap between the language of culture and the language of management and science. By using mapping and GIS, new tools could be developed that bridge this divide.

CHAPTER 1:

Documenting Subsistence Values: Traditional Knowledge as a Source of Information in Resource Mapping

ABSTRACT

Concerns over fishing opportunities and recent harvest outcomes in the Sitka Sound subsistence herring fishery have led to numerous battles within the policy arena, particularly over the protection of culturally and ecologically important herring spawn areas. In order for managers and policy makers to craft effective regulation to protect subsistence opportunities, social scientists must gather practical and useful information on the qualitative and quantitative aspects of this customary and traditional fishery. With recent policy actions directed towards creating "subsistence only" space, this research must also seek to understand the role that geography plays in where harvesters employ fishing effort. Using methods of ethnography, this paper seeks to answer the question "what do high harvesters value when choosing subsistence harvest areas?" Documenting Traditional Ecological Knowledge (TEK) on spatial aspects of the fishery also lays the foundation for future work on developing Social-Ecological Systems (SES) as part of a more holistic explanation on the role of spatial resilience in this fishery.

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1.1 Introduction

In recent years there have been several annual shortfalls in harvest levels of pacific herring roe (*Clupea pallasii*) in the Sitka Sound subsistence fishery (Holen et al. 2011). These failures to meet the minimum Amount Necessary for Subsistence (ANS) come in the wake of increasing commercial harvests within the Sound (Hebert 2011). When concerns over the availability of subsistence resources spill over into the public policy arena, social scientists with the Alaska Department of Fish and Game (ADF&G) – Division of Subsistence are tasked with providing practical and culturally relevant data to managers and policy makers. This data provides qualitative context as well as quantitative analysis on harvest patterns and the importance of the resource from the local to statewide scale. Since recent policy solutions have relied on the allocation of space, closing commercial fishing in order to create a "subsistence only" zone (5 AAC 27.150), it's important that further research and analysis incorporates elements of space as well. Specifically, this research must address what high harvesters (who constitute a majority of the subsistence effort) prefer when they practice their traditional subsistence lifestyle. Reconnecting the resource and those who rely on it in a spatial context emphasizes the mutual relationship that harvesters and herring have with the marine landscape.

To address these concerns, the first objective of this research project sought to address a simple question; "what do high harvesters value when choosing subsistence harvest areas?" To answer this, the researcher turned to Traditional Ecological Knowledge (TEK) and methods of cultural anthropology and ethnography. Working as a graduate intern with the Alaska Department of Fish and Game – Division of Subsistence, the researcher spent time in Sitka Alaska during the spring and summer of 2012, observing harvest practices and interviewing high harvesters in the subsistence herring fishery. The purpose was to detail the spatial aspects of the fishery, identify quantifiable variables that determine where harvesters choose to harvest, and to gather spatial data that would be the foundation for further work in building a social-ecological system (SES) using a geographic information system (GIS) approach.

One of the biggest challenges to applying resilience theory through a SES framework lies in the ability to statistically test empirical hypotheses (Bennett et al. 2005). Bennett et al. offer a solution to this dilemma. They propose using simplified systems models as a framework for determining “resilience surrogates”. These surrogates are defined as “attributes of systems that are related to the resilience of the system and are measurable”. Bennett et al. also outlines a four step process for identifying these attributes and developing appropriate simple system models to map their interactions. The methods and results discussed within this paper are directly related to the second step of the process that is entitled “Identifying Feedback Processes”. This step is important because these feedback processes define the system of interest and constitute the interactions that also influence the problem of interest (see Introduction). In this particular case, the problem of interest is why needs for subsistence herring roe aren’t being met and how that relates to changes in spatial attributes of the SES. To identify relevant feedback processes, TEK from high harvesters was collected and analyzed to define what spatial attributes are important in the selection of subsistence harvest areas. High harvesters were of particular interest because they constitute the bulk of the herring roe harvest and are more likely to hold useful information on the subject. The practice of relying on harvesters to supply input on spatial processes is one that Cumming (2011) describes as "winnowing down" and builds on a body of work that seeks to utilize TEK to inform science and policy in a practical and culturally relevant way (Agrawal 1995, Berkes et al. 2000, Calamia 1999, Garcia-Quijano 2009, Huntington 1998, 2000, Johannes 1998).

1.2 Methods

To capture Traditional Ecological Knowledge and other descriptive aspects of participation in the subsistence herring roe fishery, anthropological methods (approved in coordination with ADF&G Division of Subsistence protocols) were employed. This consisted of a mixture of three ethnographic and survey sources of information; 1) Participant Observations, 2) Key Respondent Interviews with Participatory Mapping, and 3) ADF&G Annual Household Survey Data.

1.2.1 Participant Observations

For the participant observations portion of the study, the researcher traveled to Sitka for several days while herring were actively spawning. Arrangements were made with a local high harvester as well as with the Sitka Tribe of Alaska Traditional Foods Program to go out and participate in the setting and hauling of roe on branch sets. During these trips the researcher received hands on instruction in how to select the best trees for large branch sets, how to prepare the trees, and what kind of areas are best for sets. These trips were primarily documented through the use of photography across all of the various stages of setting, checking, and retrieving branches throughout the active spawning event.

Key images and descriptions can be found in Appendix 1.1. Participating in these activities helped to inform the researcher on the nuanced role that geographic and temporal scales play in making successful high harvest sets. Through participation in the subsistence fishery, the researcher also gained a better appreciation for the amount of work involved in gathering herring eggs as well as insight into how the fishery is prosecuted and what makes an area “valuable” from a social ecological viewpoint.

1.2.2 Key Respondent Interviews and Participatory Mapping

To gather key respondent data, the researcher returned to Sitka in mid-May to meet and interview local high harvesters and knowledge holders. Interview guidelines and questions were developed and approved in conjunction with ADF&G Subsistence Division staff as part of the researchers graduate internship training. STA provided a list of known harvesters and helped to narrow the list down to 30 ideal candidates. Criteria for selection included: 1) Past and present high harvesters, 2) wide range of vessel sizes and 3) individual users and those who share community wide. This was done in an attempt to cover a broad range of knowledge and experience among harvesters. Once the list of candidates was compiled, potential respondents were contacted either personally by the researcher and Subsistence Division staff, through personal contact at community and tribal events during the week, or through the Sitka Tribe of Alaska office and their Local Research Assistant (LRA). Of the 30 potential candidates, 6 were available for interviewing during the time researchers were in town.

Most of the interviews were conducted at the STA Resource Protection offices, with one being conducted at the Juneau ADF&G Subsistence Division offices. Before each interview, respondents were provided with a State of Alaska issued consent form and key respondent invoice form so that they could be reimbursed for their valuable knowledge and time. Maps, notes, recordings, and summaries were only identified by a household ID number generated on the annual survey household ID list, and later replaced with key respondent numbers assigned based on the order of interviews. All originals and digital copies were filed and stored with ADF&G. All the interviews held at STA were recorded and done so with the consent of the respondents. The interview at the Juneau office was conducted by Subsistence Division staff while the researcher was still in Sitka. It was not recorded and had a less comprehensive mapping component but still contained valuable information. Each respondent was prompted with questions from a standardized list and encouraged to expound into other relevant topics relating to herring use and stock health. Notes were also taken by interviewers to later reference to the recordings. Maps of Sitka Sound highlighting key areas at various map scales were provided during all of the interviews held at STA and respondents were encouraged to highlight and annotate them as they talked. Those who were active harvesters were provided with a list of areas included in the annual ADF&G subsistence survey. They were asked to rank those areas based on personal preference (given ideal conditions) and to provide brief reasons as to why they preferred each area. Fig. 1.1 is a snapshot of the Harvest Area Preference survey instrument.

Because some areas where ranked more often than others, the ranks for each location were summed and divided by the number of responses squared (to give more weight to areas that people ranked more often) using the following equation:

$$R_i = \frac{\Sigma r_i}{n_i^2}$$

Where: R_i is the Area Rank for the i^{th} area.

r_i is the response value for the i^{th} area.

n_i is the number of respondents who ranked the i^{th} area.

A weighted rank (WR) was then calculated using the following equation:

$$WR_i = \frac{R_i}{\min\ R}$$

Where the min R was equal to 0.375.

To standardize the weighted rank into a Preference Index where values fell on a simple 0 – 1 scale (1 being Most Preferred) the inverse of the weighted rank was used.

After returning to Juneau, the researcher reviewed the interview recordings and compiled individual case studies that summarized the key concepts discussed in each interview. Each summary also documented at what point during the interview each concept was discussed and included supporting quotes. Case studies were then sent back to their respective respondent for approval. This was done to make sure that the each interview had been transcribed accurately and represented the values and beliefs of the respondent. From these summaries, the researcher extracted those attributes that were relative to spatial aspects of where people choose to subsistence harvest herring roe. Those values were tallied across all interviews to determine which ones were mentioned most consistently across all case studies. This information served as a guide for the spatial analysis portion of the project. Area preferences were compiled based on the rankings provided by respondents. A table of key characteristics for each respective area was also created from this data.

1.2.3 Household Surveys

ADF&G Division of Subsistence has been conducting household surveys of herring roe harvesters and users since 2002. The survey has undergone several changes over the years, with locational data being incorporated in 2010. Household participation rates and total harvest amount (lbs.) have been recorded for the entire period. The survey is administered to harvesters as well as consumers of the resource so that information on community and statewide sharing can also be captured. It has also been used to record qualitative information regarding the success of the subsistence fishery and community concerns over management of the resource. Further information on the methods and results from this long term study are in Division of Subsistence Technical Paper No. 343 (Holen et al. 2011).

1.3 Results and Discussion

1.3.1 Participant Observations

The participant observations served as an excellent source of context as to the amount of time, effort, and knowledge involved in harvesting roe on branch herring eggs. It also helped the researcher build rapport with members of the community and created opportunities to discuss the significance of the research, helping to better frame and refine the research questions and objectives in the process.

For harvesting herring roe on branches, the best trees are young hemlocks with small and tender needles. These needles make home preparation, including the cooking and removing eggs, easier later on. For large sets, branches should be well covered with needles, since this is the portion of the tree that is most efficiently harvested after eggs are deposited. Trees should also be free of moss, which gets tangled up in the eggs and decreases the quality. Some people collect trees in advance, hauling them out to the sites in their skiffs; others collect from shorelines on public lands in nearby areas. These trees have to be easily accessible by skiff and are often adjacent to wide flat beaches. Both of the harvesters that were observed on these trips relied on the later method of collecting trees from such areas.

For each "set" made, several trees were tied together on the beach using rope to create a "string" or "skate" of trees. The exact number of trees in a set varied between 2 to 4. Each set was then pulled from shore and kept afloat alongside the boat. Trees in the set were weighted down with one or two rock bags, which consist of a single large rock roughly 8 to 12 inches in length bound up in mesh netting and tied with twine. Once the rock bags are secured the trees are sunk into place and at either end of the skate a buoy of some sort is attached. This can either be a small Styrofoam float, empty coke bottle, milk jug, or something as large as an inflatable buoy. The purpose of the buoy is to serve as a marker during high tides, when trees can be a few fathoms below the water's surface. It was also learned that some harvesters don't use buoys. They simply set the trees, marking them with GPS or visual references, and then drag the trees up later with a grappling hook. This is believed to cut down on the amount of theft that occurs because sets aren't as easy to spot.

Areas were predominantly chosen based on the presence of active spawn, which is evident by the amount of milt in the water and the presence of herring "flipping" along the beaches (see Fig. 1.2 and Fig. 1.3). The most productive areas are often just a few hectares large and may contain a dozen sets or more. Sets were made in protected coves or island passes characterized by steep rocky shorelines and away from any known sources of sand. One harvester commented that while it was ok to make a set near one rocky outcropping, that moving the set just a few meters west would put it near a known sandbar. It was also pointed out during observations that shoreline vegetation generally included rockweed and various species of green algae, specifically sea lettuces of the genus *Ulva*. *Macrocystis* kelp was also observed in most areas. Sets were checked daily for quality of deposition. If an area "slowed down" sets were often shored up alongside the boat and hauled to nearby locations that were thought to be experiencing more active spawn. The researcher was involved in multiple trips during the short duration of the 2012 herring spawn and was able to witness firsthand how much variation there can be in spawn activity and deposition from location to location on a daily basis.

As sets receive sufficient deposition, or the spawning activity tapers, branches are harvested for distribution and processing. Leaving branches in too long can encourage algae growth which diminishes egg quality. On the "haul back" the float line is retrieved and the set may be pulled by hand or with the aid of a "pot puller", a small gas powered engine hooked to a fly wheel, usually by hydraulics. As each tree comes up, limbs and branches are clipped right off of the tree trunk and piled into the boat, usually on a tarp to keep the eggs clean and free of trash. Any branches that are too sparsely covered with eggs are generally left on the tree and returned to the water to hatch. Trimmed trunks are also left in the water. If trees are too sparse to harvest, the tree or whole set is likely to be left unharvested with the hopes that the eggs will hatch. Methods for processing the eggs can vary widely; most people seem to prefer to keep the eggs on larger branches, which make the blanching of eggs easier. The STA Traditional Foods Program trims down the product more than most which makes it easier to bag or box eggs on branches for distribution to elders.

1.3.2 Key Respondent Interviews and Participatory Mapping

From the key respondent interviews, 17 key themes regarding harvest site selection were identified. These themes were subdivided into factors that attract harvest effort (10), and those that deter effort in areas (7). Favorable factors include active spawn, protection from waves, depth, number of consecutive spawning days in an area, protection from wind, consistent annual production, presence of rocky substrate, presence of kelp, close proximity to harbors and other points of access, and relative abundance of fish (generally staging just off active spawn areas while they mature). Factors that detract from an area included presence of sand, run off pollution from town and the airport (including trash and sewage), nearby sources of fresh water (such as the outflow of rivers), presence of *d.vex* (a fast spreading invasive tunicate found currently in Whiting Harbor), mud, and the socioeconomic factors of cost (in terms of price of fuel) and lack of time. Of the favorable factors, active spawn was the only variable mentioned in all 6 accounts. Protection from waves came up in 5 of 6, depth and spawning days in 4 of 6, and protection from wind and consistent production came up in half. Rocky substrate, presence of kelp, close proximity to town, and relative fish abundance were mentioned in less than half the accounts (See Fig. 1.4)

Each of these attributes represents social and/or ecological values associated with the harvest of herring roe. Protection from wind was specifically mentioned in some accounts as being more important from a harvest perspective, since it's hard to pull branches in smaller skiffs when high winds can blow the craft around. Protection from waves had social and ecological connotations, because waves can make harvest difficult much in the same way wind does, and also because waves stir up sand, sediment, and presumably eggs themselves. Sand and sediment reduce egg quality while dislodged eggs reduce harvest quantity and could presumably affect egg survival (for eggs not harvested). Fuel costs, proximity, and availability of time are social attributes that are all related to accessibility.

It's worth noting that three of the attracting factors (active spawn, spawning days, and consistently productive) are effectively one variable across three temporal scales. Active spawn is a single day event, spawning days are multiple days of active spawn within a year, and consistently productive areas receive multiple spawning days from year to year. This demonstrates a high degree of spatial and temporal dependence between subsistence harvesters and key spawning areas and will be discussed further in later chapters.

From the participatory mapping exercise, two key pieces of information were extracted. The first was a better definition of harvest area boundaries for the 19 locations in the study area (derived from the ADF&G annual household survey) (See Appendix 1.2). Some areas were mapped better than others. This level of detail corresponded closely with areas that were either more preferred or that had received more day to day spawn activity within recent times. This is covered in more detail in Chapter 2, because these areas were used in the spatial analysis portion of the research.

The second piece of information was establishing a baseline preference for each particular harvest area. Table 1.1 shows the results of this ranking exercise. South Middle Island, Kasiana Island, Crow/Gagarin Island, and North Middle Island all belong to the "core" area. This area was at the heart of the Subsistence Only Zone debate during the 2012 Board of Fish meetings. It's also important to note that there was a greater degree of consistency in providing reasons **why** each area was preferred. Important attributes at a more site specific scale only included productivity, proximity to town, quality and density of kelp beds (generally *Macrocystis*), and protection from wind and waves. There was also a high degree of consensus on many of these attributes within specific areas (Table 1.1). This is likely due to the fact that experiential knowledge is commonly shared in this fishery, as all of the respondents mentioned being trained on how to harvest by family and community elders. This shared cultural heritage and identity would help explain the homogenous nature for site preference and commonalities in what makes an area significant. A larger sample size would have better demonstrated this point, but for the purposes of this project the results appear to be representative of commonly held beliefs.

In order to gauge just how accurately the rankings captured location preferences for the larger population of subsistence harvesters, the rank values were plotted against the cumulative household responses for subsistence areas. This was done using combined data from the 2010 and 2011 household survey as the response variable. To fit the ranking values on a scale of 0 to 1, the inverse of the weighted ranks (from Table 1.1) were used and all non-responses were given a value of 0. By doing this, the x axis represents a scale of 0 to 1, with 1 being “Most Preferred” and 0 being “No Preference”. Figure 1.6 graphs this relationship and demonstrates a positive correlation between where people prefer to harvest and how many households actually attempted to harvest in those areas for the years 2010 and 2011. The fitted regression was significant at $p < 0.01$ with an R square value of 0.77. Excluding Aleutkina Bay (an outlier site that was only preferred by one respondent but hasn’t seen any spawn activity in recent time) increases the R square value to 0.84. The sample size in the preference survey was relatively small (n=4) and yet it effectively captures and explains variations in where households chose to harvest for the two years of data available at the site specific scale. This suggests that the results from the harvest area preference survey are representative of the larger population of subsistence herring roe harvesters during this time period.

1.4 Conclusions

These methods demonstrate the effectiveness of using ethnographic tools in characterizing spatial attributes that are important to subsistence harvest areas. Some aspects of this data were more qualitative and nominal than others (Fig. 1.4 and 1.5 for example). From this information it’s hard to quantify just how much more important active spawn is compared to consistent productivity. While it’s difficult to attach a strong quantitative value to these aspects through ethnography alone, the methods and results provide a crucial starting point for “winnowing down” key spatial aspects of the fishery itself (Cumming 2011). In the context of this research project, many of these variables can be mapped using GIS and existing data sources to incorporate a quantifiable and statistically rigorous means of comparison. It is clear from the simple key respondent coding exercise that people tend to fish where the fish are. It's not entirely clear whether the remaining variables are truly independent to attracting harvest effort, or whether they are simply intervening variables that attract herring spawn. Comparisons of the ecological role of some of these attributes will be addressed more thoroughly using spatial analysis in subsequent writings (Chapter 2 of this thesis).

Not all of the data collected was qualitative. The harvest area preference survey was an attempt to incorporate more quantitative measures into the ethnographic portion of the research. This exercise also shows the effectiveness of targeting a small group of knowledgeable harvesters when shared values are common. By conducting the harvest area survey with 4 active harvesters, an index of preferred areas was created that effectively explained variation in household effort for the years 2010 and 2011.

Participant observation, key respondent interviews, and household surveys are all standard tools employed by ADF&G Division of Subsistence in documenting the cultural significance of subsistence activities in the daily lives of Alaskans. This cultural context is important in informing management decisions at the local and regional level, through area management biologists and regional managers, as well as at the state level, through the Board of Fish and Board of Game processes. Unfortunately, many biologists and policy makers don't adequately speak the language of culture and social science. Because of this it is important that cross cultural tools of communication exist that translate from qualitative to quantitative. Providing opportunity for participants in the fishery to define space in a way that is meaningful to them is simply the first step.

Tables

Table 1.1 Results from Harvester Preference survey showing preference scale (0 = "not preferred/used" 1 = "most preferred") and key reasons for preference.

ID	Location Name	Pref. Scale	Reasons
1	Kasiana Island	0.86	Productive(3);Proximity(1)
2	North Middle Island	0.42	Productive(1);Proximity(1)
3	South Middle Island	1.00	Productive(3);Protected(1)
4	Crow/Gagarin Island	0.46	Quality Kelp(3)
5	Gavanski Islands	0.00	
6	Siginaka Islands	0.00	
7	North Japonski/Whiting	0.25	Quality Kelp(2)
8	South Japonski/Mermaid	0.00	
9	Causeway Islands	0.00	
10	South HPR	0.00	
11	North HPR	0.19	Protected(1)
12	Eastern/Promisla Bay	0.00	
13	Magoun Isle/Hayward Strt	0.00	
14	Katlian Bay	0.00	
15	Apple/Parker Group	0.19	Quality Kelp(1)
16	Crescent/Jamestown	0.25	Productive(1);Proximity(1)
17	Camp Coogan/Sandy Cove	0.00	
18	Aleutkina Bay/Leesoffskaia	0.38	Proximity(1)
19	Samsing/Three Entrance Bay	0.00	

(n=4)

Figures

Assuming active spawn, Rank each area according to preference, No Response = No Preference/Use. Give key reasons for each ranked area

Survey ID	Location Name	Rank	Reasons
1)	Kasiana Island	______	____________________
2)	North Middle Island	______	____________________
3)	South Middle Island	______	____________________
4)	Crow/Gagarin Islands	______	____________________
5)	Big/Little Gavinski	______	____________________

Fig. 1.1 Snapshot of survey instrument used to capture harvest area preference. Area names were taken from ADF&G Annual Household Survey. This survey was administered to respondents during the Key Respondent Interviews to capture which areas are most preferred for harvest, given ideal spawning conditions, and to capture why certain areas were more preferred.

Fig. 1.2 Herring Milt and Macrocystis Kelp

Fig. 1.3 Herring “flipping” along rocks

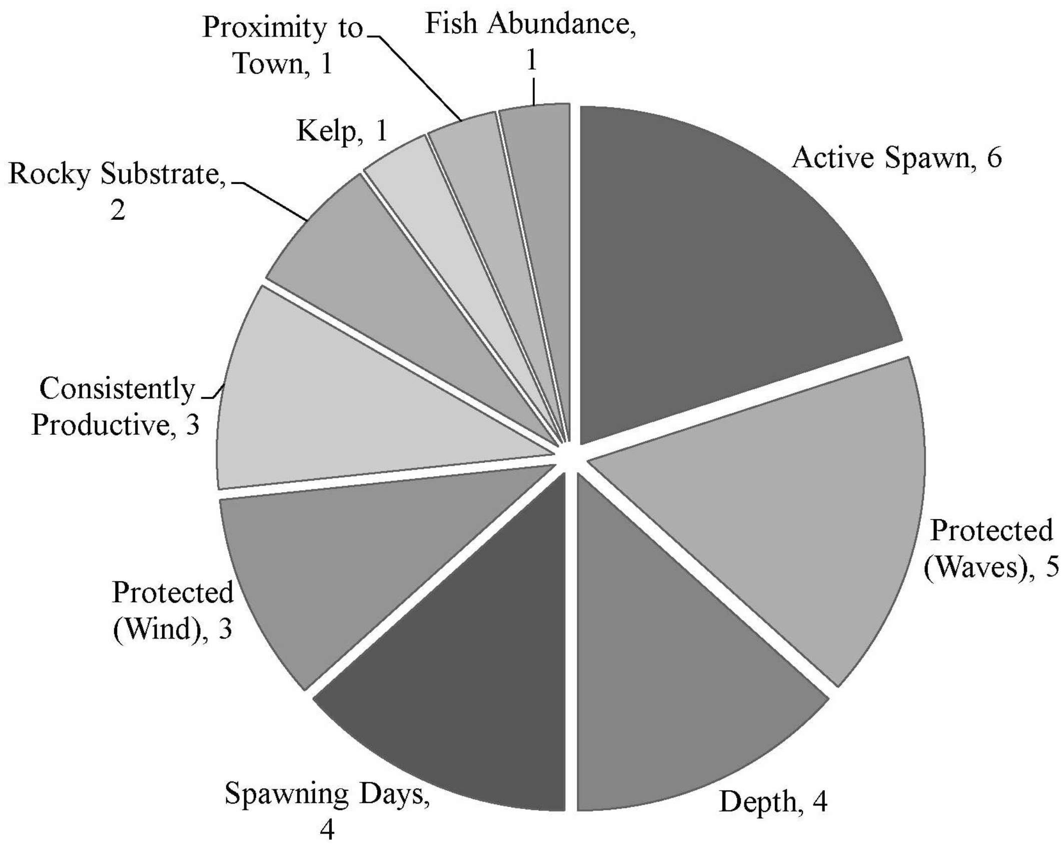


Fig. 1.4 Key factors that attract participants to harvest areas. Categories were compiled based on responses given during Key Respondent Interviews. Results were simply tallied as "mentioned" for each respondent without regards to how often a respondent mentioned them. (n=6)

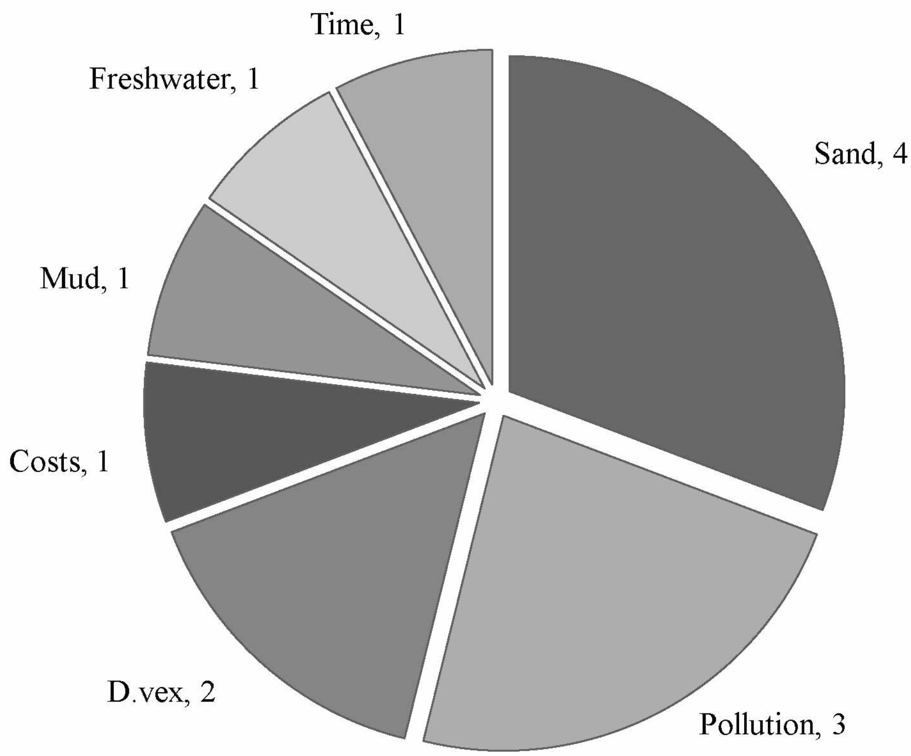


Fig. 1.5 Key factors that deter participants from potential harvest areas. Categories were compiled based on number of responses given during Key Respondent Interviews. Results were simply tallied as “mentioned” for each respondent without regards to how often a respondent mentioned them. (n=6)

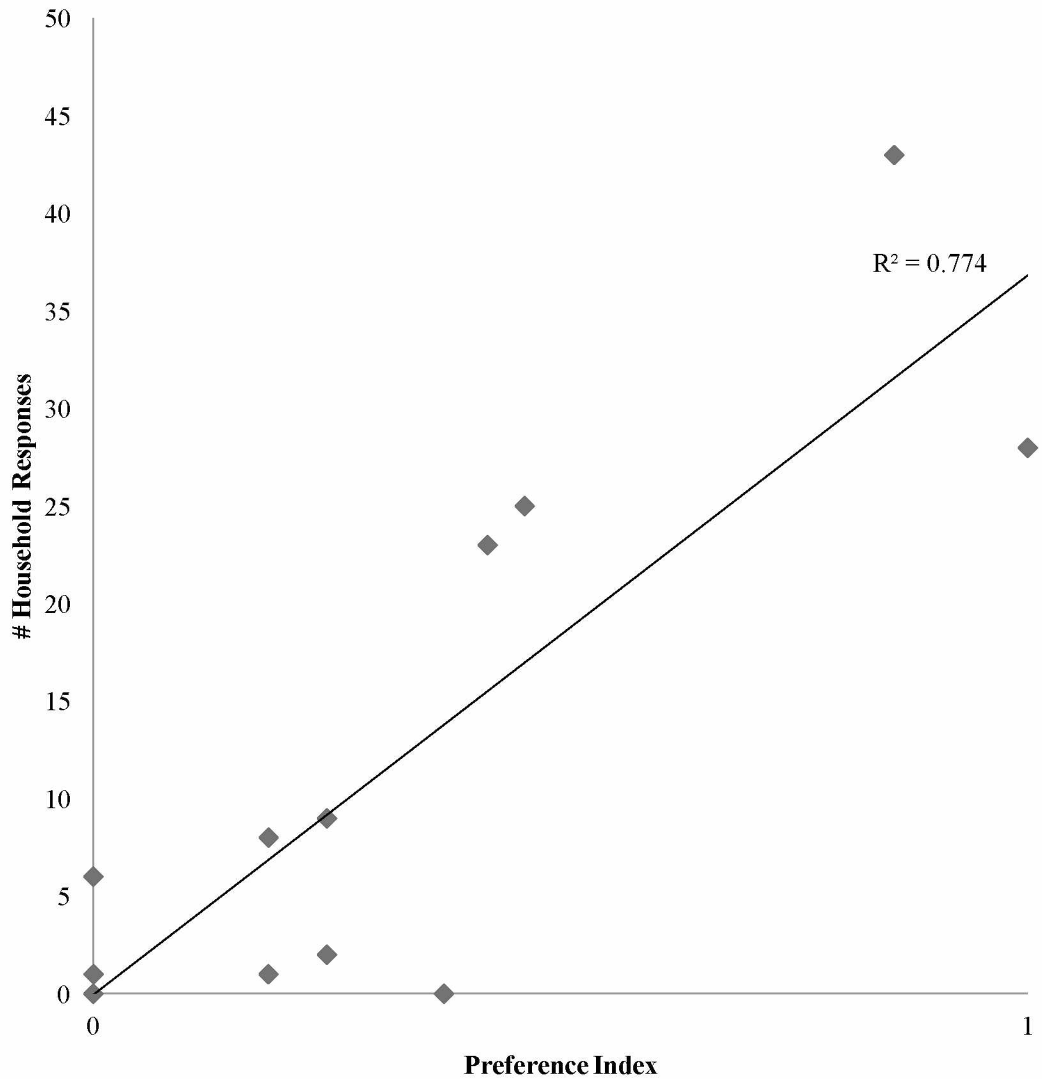


Fig. 1.6 Preference Scale vs. Household Responses of locations where households attempted to harvest (2010-2011). Zero preference means that the area was not ranked, a preference of 1 signifies the most preferred area based on survey data.

Appendix 1.1 Select images from subsistence herring egg harvest


A popular harvest area on South Middle Island


Macrocystis kelp in an area of active spawn


Rocky shoreline near harvest location


Dragging a skate of trees out to set


Tying rock bags to trees


Checking sets for egg deposition thickness


Branch with “decent thickness”


“Heavy thickness” of eggs on a branch


Pulling branches and untangling the skate


Trying to find a submerged float at high tide


Tree trunk handling


Cutting branches at the trunk

Appendix 1.2 Maps from respondent interviews detailing subsistence use areas

Sitka Sound Subsistence Herring Use: Sitka Sound

About The Maps:

These maps represent subsistence herring harvest areas for Sitka Sound. Areas were defined based on information gathered during key respondent interviews in May 2012.

This information was used in drawing comparisons between areas of subsistence use versus non subsistence use.

Subsistence Harvest Areas

Greatest Input

Least Input

0 1 2 4 Miles

1:128,000

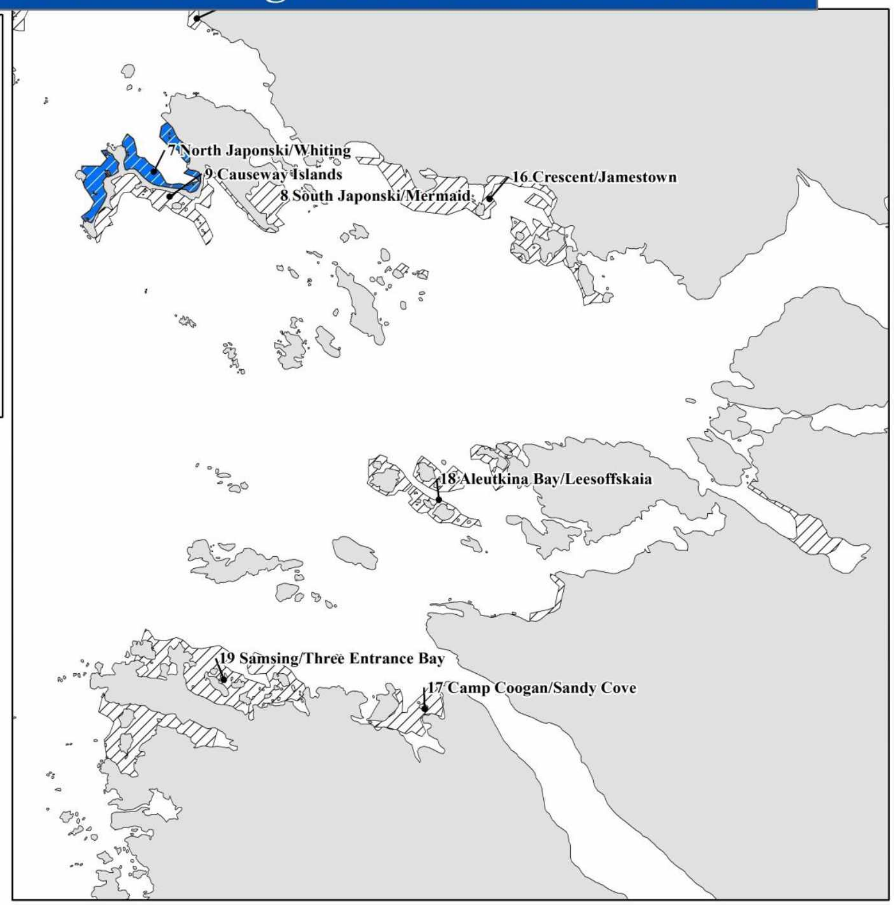
Page 1

Sitka Sound Subsistence Herring Use: South Harvest Areas

About The Maps:

These maps represent subsistence herring harvest areas for Sitka Sound. Areas were defined based on information gathered during key respondent interviews in May 2012.

This information was used in drawing comparisons between areas of subsistence use versus non subsistence use.



Subsistence Harvest Areas

Greatest Input

Least Input

0 0.5 1 2 Miles

1:64,000

Page 2

Sitka Sound Subsistence Herring Use: North Harvest Areas

About The Maps:

These maps represent subsistence herring harvest areas for Sitka Sound. Areas were defined based on information gathered during key respondent interviews in May 2012.

This information was used in drawing comparisons between areas of subsistence use versus non subsistence use.

Subsistence Harvest Areas

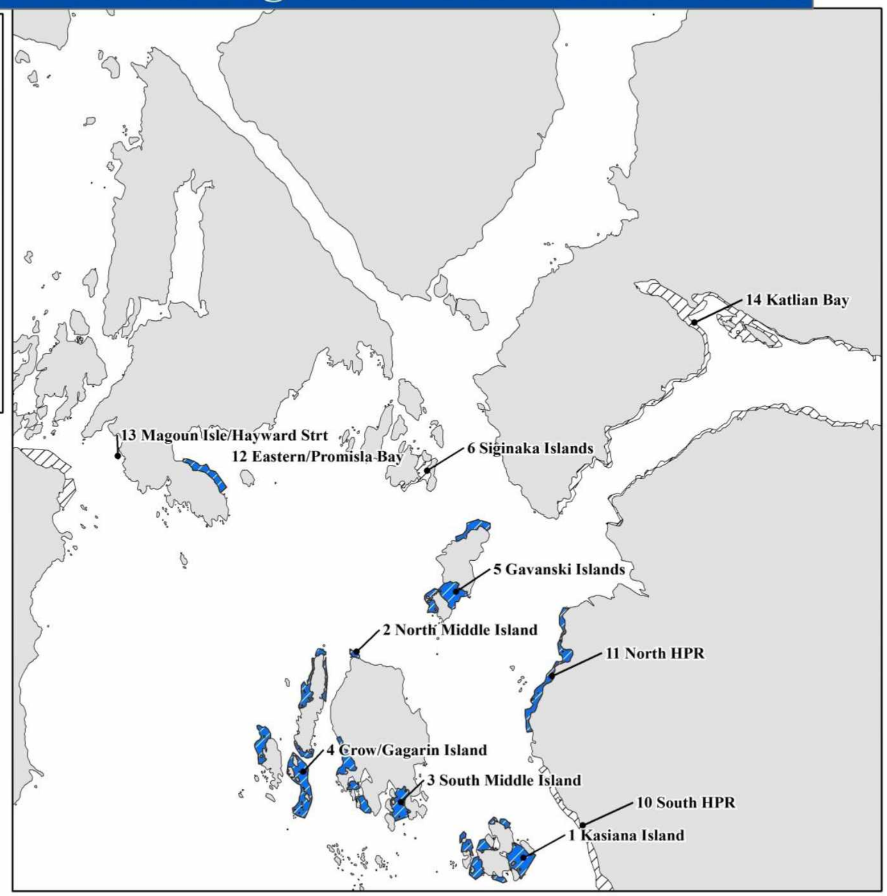
Greatest Input

Least Input

0 0.75 1.5 3 Miles

1:96,000

Page 3

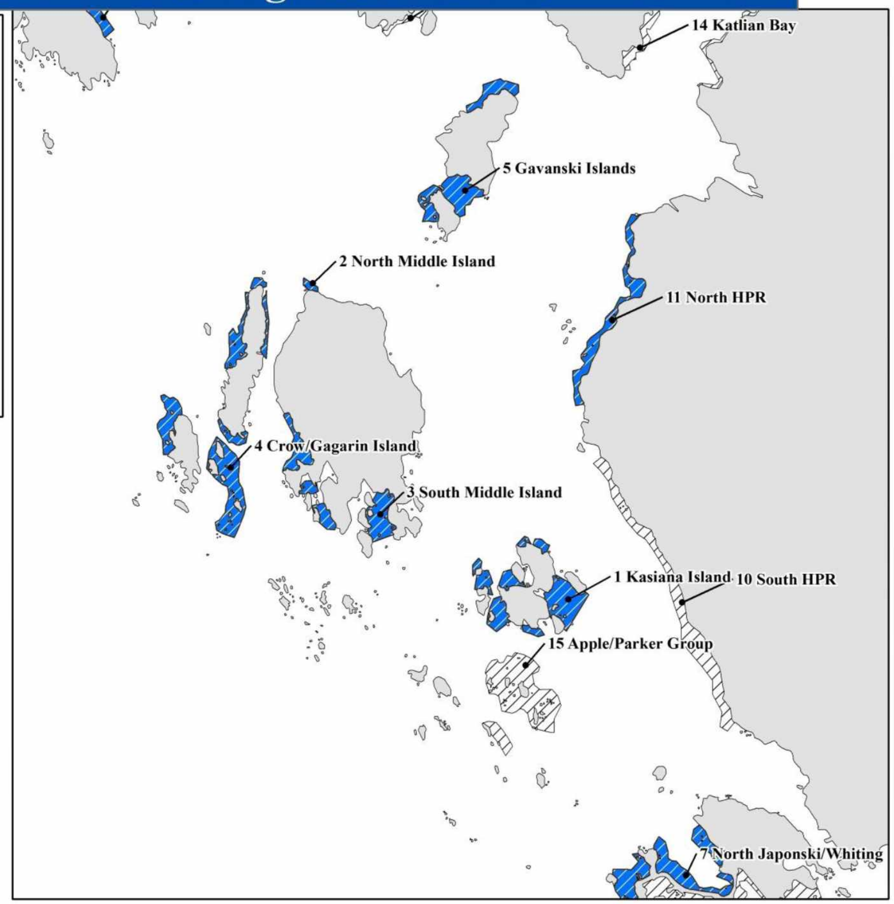


Sitka Sound Subsistence Herring Use: Core Harvest Areas

About The Maps:

These maps represent subsistence herring harvest areas for Sitka Sound. Areas were defined based on information gathered during key respondent interviews in May 2012.

This information was used in drawing comparisons between areas of subsistence use versus non subsistence use.



Subsistence Harvest Areas

- Greatest Input
- Least Input

0 0.5 1 2 Miles

1:63,000

Page 4

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CHAPTER 2:

Mapping and Translating Cultural Values: Building a Social-Ecological Landscape for Analyzing Resilience.

ABSTRACT

This paper details spatial analysis techniques used to quantitatively evaluate spatial attributes found in Traditional Ecological Knowledge (TEK). The purpose of this analysis is to develop a Social-Ecological System (SES) by linking these system attributes. Once the SES is defined, it should be possible to identify which components contribute to success in the subsistence herring fishery. A Geographic Information System (GIS) approach was chosen to perform the spatial analysis. Using GIS has many advantages including graphic representation of variables and values, ease of compiling and integrating multiple data sources into a consolidated geodatabase, and access to powerful statistical tools. Following spatial analysis, these spatial attributes are connected to create a SES for the subsistence fishery.

2.1 Introduction

In order to analyze attributes of spatial resilience in a social-ecological system, a model of the system must first be developed. To do key components of the system must be identified, related and connected, and then assessed within the context of resilience theory. For this project, ethnographic research provides the basis for determining model components for the system including Sitka Sound, herring, and subsistence harvest (Ch. 1). To construct the SES, a Geographic Information System (GIS) was used to compile data, analyze relationships, and piece together the system attributes so that resilience surrogates could be identified (Bennett et al. 2005).

This paper covers the second objective of the thesis; to map the social-ecological system (SES) that includes subsistence use of pacific herring (*clupea pallasii*). This objective seeks to address the question of whether GIS can be used to perform spatial analysis of system attributes and develop a general model for subsistence harvest. The SES attributes were derived from ethnographic methods and Traditional Ecological Knowledge (TEK) (See Chapter 1).

A GIS approach was chosen for several reasons; one reason being the strength of GIS as a tool for rapidly symbolizing and mapping spatial attributes. This allows for the graphic representation of complex spatial phenomenon in very simple ways. Doing so also provides a means for visually communicating information in a cross cultural and interdisciplinary fashion (Calamia 1999).

An additional factor was the availability of existing data. Alaska Department of Fish and Game (ADF&G) already collects a large amount of herring data in spatial form, particularly in terms of daily spawning patterns of herring. Great strides have also been made in creating extensive habitat databases of Alaska's marine environment. One such project is the National Oceanic and Atmospheric Agency's (NOAA) ShoreZone database.

Utilizing existing datasets reduces the amount of time required to collect and analyze data and provides opportunity for comparison should similar projects be attempted in other areas of the state. These datasets were supplemented with ethnographic data to provide comparative analysis on subsistence/non-subsistence harvest areas at different scales. This information included spatial boundaries for subsistence areas, which were constructed in the GIS database from information collected through ethnographic research (see Appendix 1.1).

Once the data is compiled and merged together into a single geodatabase, a GIS approach provides simple and powerful methods for calculating summary and descriptive statistics (Calamia 1999). These statistics were then used to study the relationship that herring and subsistence harvesters have with each other as well as with the environment. This spatial analysis helps to develop the linkages between the systems attributes so that a formal SES model can be developed.

The finalized model demonstrates how subsistence herring egg harvest effort is connected to the landscape, and the overlapping connections between herring spawn distribution and subsistence harvest areas. Subsistence harvesters are closely connected to the marine environment through several spatial processes, and success in the fishery is determined largely in part by the overlap between these areas and herring spawn. This connection between spatial distributions and resource access is important and often overlooked in other modeling approaches (Calamia 1999, Cumming 2011, Johannes 1993, 1998).

2.2 Methods

2.2.1 ShoreZone

To build a SES for subsistence herring in Sitka Sound, ethnographic information was combined with existing spatial data. Two primary datasets were used in this process. The first was the National Oceanic and Atmospheric Administration's (NOAA) ShoreZone database for Sitka Sound (Shorezone.org 2012). ShoreZone is a "standardized system [that] catalogs both geomorphic and biological resources at mapping scales of better than 1:10,000. The high resolution, attribute rich dataset is a useful tool for extrapolation of site data over broad spatial ranges and creating a variety of habitat models." ShoreZone (ibid.) contains attributes for shore substrate, vegetation types, and exposure to wave action, among other things.

2.2.2 Aerial Spawn Surveys

The second source of data was 12 years' worth of digitized aerial spawn maps from ADF&G – Commercial Fisheries Division. These digitized maps depict daily shoreline stretches of active spawn for Sitka Sound. This dataset was received with each day of spawn being mapped to a separate ArcGIS shapefile and each year grouped into separate folders. To better query the information, each shapefile was given a Spawn Date attribute field with the values calculated using a python script that parsed the date from the shapefile title. Using ArcGIS 10.0, each shapefile was then spatially joined to a polyline feature class template derived from ShoreZone. This operation was batch processed using the following parameters; the target features were the daily spawn maps, the join feature was the template ShoreZone feature class, and the output feature was named based on the date. The join operation was "one to many" with the option to "Keep all Target Features" turned off. The match option was "Within a Distance" of 100m. Performing the operation in this way created a feature class that retained only those line segments from the ShoreZone database that corresponded to observed active spawn from the aerial surveys, with these segments receiving the Spawn Date attribute field.

Once this batch operation was completed, each day was joined into a single feature class (titled Spawn_Map_yy) for each year of the 12 year study period. Each year was checked, one day at a time, and edited against the original aerial survey shapefile for quality control. Every day within a spawn year feature class was edited in a direction from North to South and East to West. Small rock islands were left intact and larger rock islands or outcroppings were edited down where possible. The scale at which edits were made ranged from 1:6,000 to 1:11,000 with most edits at 1:8,000. Coves were left intact but line segments for long stretches of shore were edited out if the midpoint of the ShoreZone polyline wasn't within close proximity to the original spawning map lines, so that more than half the line segment was outside the spawning area (Appendix 2.2) Isolated spawning reaches within longer stretches of shoreline were also edited out rather than subdividing existing line segments in Shore zone (Appendix 2.2). In most cases, the end points for lines on the aerial survey maps matched closely with line segments in ShoreZone. Appendix 2.2 shows a comparison of the "before" (raw data) view with the “after” (processed data) view around Middle Island for a single year (left and right, respectively).

To aid in the calculation of spawn days, an additional feature class was created titled Spawn_Count_yy, so that the Date field could be changed into a short integer field. Each Date was then converted to a “1” and null dates to a “0” (Appendix 2.2). The total number of spawn days for each stretch of shoreline within a given year was then calculated and joined to the master ShoreZone database.

2.2.3 Subsistence Use Areas

The next step in creating a geodatabase for spatial analysis was to define the subsistence use areas. This was done using information gathered from key respondent interviews and participatory mapping exercises. During these exercises, respondents were encouraged to highlight areas where they had historically made sets. These maps were scanned and saved in PDF form and reorganized by plates so that all of the Map 1 plates were in a single PDF book and so forth. Areas were manually digitized in ArcGIS 10.0 using the map book to determine shoreline boundaries. To define ocean extent boundaries, polygons were drawn to contour lines representing ~2 fathoms below mean low tide, which was the maximum depth mentioned by any of the key respondents. Not all of the 19 areas on the annual survey were defined during the mapping and interview process. Those not discussed were digitized more broadly, and the Subsistence Use Area shapefile was given an integer attribute to denote which areas had the most input (“1”) and which areas had the least (“2”). Maps were then printed out and mailed to participants for review, comments, and additional input (See Appendix 1.2 and 2.1). None were returned.

After subsistence areas were defined in ArcGIS, a spatial join was performed with the ShoreZone data to extract those stretches of shoreline that fell within the defined subsistence areas. The output feature class was given the survey location ID (Id) so that each shoreline segment could be identified to its respective subsistence harvest area. These attributes were then joined to the master ShoreZone database so that shorelines outside of the subsistence use areas received an ID designation of “0”. Additional attributes were added for classifying shoreline stretches as subsistence vs. non-subsistence and most preferred harvest areas vs. all other areas (“1” and “0” respectively for both attribute types). This was done to make querying and the data analysis of the ShoreZone data easier in respect to subsistence areas.

Once these steps were complete, each dataset was packaged into a single consolidated geodatabase. From this database several sets of spatial statistics were calculated and analyzed in order to compare aspects of the system at different social and ecological scales. The variables of interest were derived from key respondent interviews (Fig. 1.4) and included factors such as shore substrate type and shoreline exposure to wave action (fetch). Spatial scales were divided into two categories; ecological and social. The ecological category focused on spatial distributions of where herring spawn. The social category was based on areas of subsistence/non-subsistence use. Values from both categories were also compared to the Sitka Sound area as a whole. Aggregating the analysis into social and ecological categories was an important step to better understanding the overlap in herring spawn site selection and where subsistence harvesters choose to harvest.

2.2.4 Cluster Analysis

In order to measure spatial distributions of herring spawn and establish the ecological category, cluster analysis was performed at the global (study area wide) and local (individual line segments) scale using the ArcGIS Spatial Autocorrelation (Global Moran's I) tool and the Cluster and Outlier Analysis (Anselin Local Moran's I) tool, respectively. The input field for both cases was the total number of spawn days throughout the 12 year period and the spatial relationship was inverse distance. This was an important step in statistically proving whether historical spawning patterns were dispersed, random, or clustered. Global Moran's I establishes whether or not the area of interest exhibits statistically significant spatial autocorrelation (clustering) (Mitchell 2009, Getis and Ord 1992). Once that was documented the next step was to use the Cluster and Outlier Analysis (Anselin Local Moran's I) tool. This tool compares the input value for each individual line and its neighboring line segments to the global mean; this is the local index (I). The tool calculates z-scores and p values for each local I. It automatically organizes each segment into one of four fields based on cluster type; statistically significant (at the 0.05 level) high value clusters (HH), low value clusters (LL), high outliers surrounded by low values (HL), and low outliers (LH) (ArcGIS Help Library 2012). Cluster types were added to the ShoreZone database under the "COType" attribute. For comparisons within the ecological category, high value clustering, low value clustering, and not statistically significant shoreline stretches were used as treatment groups. Outliers were not considered in analysis as they constituted such a small percentage of total shore (less than 1 percent) and were generally found in boat harbors.

2.2.5 Fetch/Wave Exposure

To measure exposure to waves, summary statistics were run tabulating shore length (m) for Exposed, Semi-Exposed, Semi-Protected, Protected, and Very Protected stretches of shore at each of the different social-ecological scales. In order to draw comparisons across scales, the length (m) was converted to percentage of total length within each category.

2.2.6 Shore Type

The last spatial attribute considered was shore type and substrate. While this attribute wasn't consistently mentioned in key respondent interviews, it has come up as a factor in other accounts (Thornton et al. 2010) and is easily quantifiable using ShoreZone data. Shore type in ShoreZone is classified under the "BC_Class" attribute, and is based on the Howes et al. (1994) methodology (in Harper and Morris 2004) first developed in British Columbia. There are 35 total classes in the "BC_Class" attribute. Classes 1-5 are rock dominated substrates with no mixed in sediment. Classes 6-20 are mixtures of rock with cobble, gravel, and/or sand. 21 through 30 are predominantly gravel to sand/mud, with little to no visible rock formations in the intertidal zone. The remaining classes cover organics (31), anthropogenic rock formations (32 and 33), channels (34), and glaciers (35) (Harper and Morris 2004, ShoreZone Data Dictionary). Shore types were analyzed and compared, with emphasis on rock or cobble/gravel substrates. This was done at the same scales as the fetch analysis. Initial comparisons were made between rock/gravel and sand/gravel substrates by aggregating classes 1-10 (rock and gravel mix) and 11-20 (sand and gravel mix). Further comparisons were then conducted on four individual classes (3,8,9, and 32) that contribute the most to both high spawn clusters and subsistence use areas. These comparisons were made consistently across the same scales as the fetch analysis.

2.3 Results and Discussion

2.3.1 Cluster Analysis

Fig. 2.1 shows the results of the global spatial autocorrelation report. For the Moran's Index, the possible range of values falls between -1 and 1. Here -1 represents evenly dispersed values, 0 represents a completely random distribution, and 1 represents a complete clustering of values for the entire study area (ArcGIS Help Library 2012). The calculated Moran's Index for total spawning days across the 12 year period is 0.88, with a global z-score of 160.06, and a p-value of 0.000. These statistics show that there's a highly significant amount of spatial clustering occurring in herring spawn days, and that there's less than a 1 percent chance of this pattern being random.

The next step in understanding spatial clustering was to identify to what extent individual stretches of shoreline were clustered together based on Anselin Local Moran's I. Appendix 2.2 contains a map depicting these classifications for all of Sitka Sound over the course of the study period. Only 12.73 percent of shoreline segments (78.9 kilometers) show a statistically significant clustering of high spawning days. Less than 5 percent is significantly clustered low values while 82.51 percent was not clustered (high or low) at statistically significant levels. Only about half of a percent was classified as outliers. Most of these outliers were harbor areas that were excluded in the editing process.

2.3.2 Overlaying Spawn Days with Subsistence Harvest Areas

Based on ethnographic data, access to active spawn at multiple temporal scales is one of the single most common factors in harvest site selection (Ch. 1). Cluster analysis provides us with a way for identifying areas that are likely to see consistently high spawn. Fig. 2.2 shows this interaction between cluster composition and the social category across harvest area scales. Only a small percentage (12.73) of Sitka Sound can be classified as clustered for high spawn days at a statistically significant level. That trend drastically shifts when harvest areas are broken out to look at non-harvest (8.45 percent) vs. subsistence harvest areas (39.85 percent). Zooming in further, the most preferred harvest areas offer an even starker contrast with 94.24 percent of shoreline being highly clustered spawn. The remaining shorelines are not clustered at a significant level. This doesn't imply that they aren't receiving high amounts of active spawn. It simply means that it's not a significant amount in relation to other nearby shoreline segments for the 12 year period.

The overlapping relationship between subsistence harvest areas and areas of highly clustered high spawning days supports the idea that there is an important spatial connection between the social and the ecological aspects of this fishery. The probability that adjacent stretches of shoreline in Sitka Sound are receiving high spawn days is low. However the likelihood that these high spawning day shoreline stretches are within a harvest area is high. This is especially true if that area is one of the most preferred for subsistence harvest activities. Further analysis will show how various spatial attributes contribute to both elements of the SES.

2.3.2 Fetch

Outside of spawning activity, another important value for subsistence harvest is protection from waves and wind (Ch. 1). The ShoreZone database includes characterization of each stretch of shoreline for exposure to fetch (wave action) under the "EXP_BIO" attribute. Fig. 2.3 shows comparisons for percentage of total shoreline within each exposure class (exposed, semi-exposed, semi-protected, protected, very-protected, and an aggregate of semi-protected or greater) across multiple scales. Scales in Fig. 2.3 that are to the left of Sitka Sound represent the ecological category based on cluster type while the scales to the right represent the social category based on harvest areas.

For Sitka Sound, 44.7 percent of shoreline is characterized as semi-protected while 78.09 is semi-protected or better. As we move through the ecological category, 40.7 percent of non-clustered shoreline is semi-protected with 73.26 percent semi-protected or better. Shoreline that is clustered for high spawn days contains 60.68 percent semi-protected shore with 95.82 percent semi-protected or better. On the social scale, non-subsistence harvest areas contain 42.97 percent semi-protected shoreline and 74.8 percent semi-protected or better while the most preferred areas are comprised of 75.85 percent and 95.97 percent, respectively.

This data shows that both herring and subsistence harvesters are more likely to rely on areas protected from fetch (waves). From a social standpoint, the protection from wind and waves makes it easier to set and retrieve branches or harvest kelp. It also reduces the chance that sand or "trash" will get stirred up and deposited in eggs and ensures that eggs will not get dislodged from branches during rough ocean conditions (interview data).

2.3.3 Shore Type and Substrates

The final step in spatial analysis comes from comparing the role of shore types and substrates within the SES. This was done primarily because the ShoreZone database features an attribute for shore type/substrate (BC_Class). It also provides a means of exploring a variable that wasn't discussed as predominantly in the ethnography as some of the other variables were.

Fig. 2.4 shows percent composition of intertidal shore types that include rock or rock/gravel substrates (BC Class 1-10 and 32) vs. rock w/sand (11-20). On the ecological side of the picture, these aggregated shore types show very little variation across the scale. Looking at the social side there is a more noticeable difference. 61.4 percent of shore line length for Sitka Sound is rock or rock/gravel, compared to 64.74 in subsistence harvest areas and 76.52 percent in preferred harvest areas. Subsistence areas are also less likely to have substrates containing rock and sand (10.69) percent although that percentage is actually higher in preferred areas (14.13).

Within the broader category of rock and gravel substrates there are four dominant shore type classes. BC class 3 is a narrow intertidal rock cliff (ShoreZone Data Dictionary) and is found in just over 15 percent of shorelines in Sitka Sound (Fig. 2.5).

Class 8 is characterized by a rock cliff with a narrow (< 30m) gravel beach and class 9 is an inclined (5-20°) and narrow gravel ramp over hard rock (ShoreZone Data Dictionary). Both classes make up 10.43 percent and 11.39 percent of shore types in Sitka Sound, respectively. Class 32 is man-made "rip rap", usually large rock and gravel placed along areas of development and construction (ShoreZone Data Dictionary). It's only found in 4 percent of Sitka Sound, but has a much greater influence at other scales.

Comparing these shore types across scales highlights several differences. Again there is a greater distinction in the composition of the social scale versus the ecological scale. Class 8 and 9 only appear 10 percent of the time in non-subsistence areas. For subsistence zones there is a slight difference of 10.56 (class 8) and 16.88 percent (class 9) and for preferred areas the percentages jump to 33.5 and 24.29, respectively. Meanwhile class 3 actually declines in prevalence; from 15.84 (non-subsistence) to 10.6 (preferred areas).

Similar outcomes exist at the ecological scale, but are again less pronounced. For high spawn clusters, class 9 dominates 17.18 percent of shoreline, followed by class 8 (14.43) and class 3 (9.22). Low spawn clusters are arranged exactly the opposite. Class 3 is more prevalent at 14.04 percent, followed by class 8 (13.51) and class 9 (11.49). The areas that are not statistically clustered as high or low once again resemble Sitka Sound as a whole.

Class 32, the man made rip rap category, offers some interesting trends for analysis as well. It's completely absent in the most preferred areas even though it makes up 10.89 percent of subsistence areas (compared to barely 2 percent of non-subsistence areas) and over 13 percent of high spawn clusters (completely absent in low spawn clusters). The difference in the social scales is due mostly to the inclusion of south Halibut Point Road as a subsistence area. While this is an area of consistently high spawn, it's generally avoided as a subsistence area because of the impacts of runoff pollution and beach trash on the quality of eggs (personal correspondence). It was included because it has historically been on the household survey used by ADF&G and it does provide easy access to a spawning area if someone wasn't as concerned about egg quality. Including it does provide an interesting contrast showing that just because an area is good for spawn (a key consideration in determining where to make sets) doesn't mean that it's good for subsistence use. There are many other factors at play that can eliminate an area from being a part of the preferred area, even when these areas are relatively nearby in space.

2.4 Conclusions

Translating spatial attributes contained within TEK is a crucial link in bridging the communication divide between culture, science, and resource management. Using GIS as a tool for spatial analysis enriches the quantitative aspect of describing and characterizing the SES for subsistence herring. It also serves as a foundation for creating a simple system model. From this model it should be possible to identify which attributes serve as resilience surrogates (Bennett et al. 2005).

This phase of the research actually covers two steps in Bennett et al.'s framework. First it further defines the system drivers in more quantitative terms and second it helps to connect the system elements and processes. From this information we can begin to piece together the larger picture of what is driving success in the subsistence herring fishery (Fig. 2.6). Sitka Sound as a whole only contains a small area of space (roughly 12 percent) that has received highly clustered high spawn days over the 12 year study period. This contrasts starkly with the most preferred subsistence harvest areas. Ninety five percent of these areas contain high spawn day clustered shoreline. From this we can start to conclude that subsistence herring harvest successfully occurs where herring spawn overlaps with harvest areas, a common underlying theme in the ethnographic data.

Fig. 2.6 depicts the system components that contribute to subsistence herring roe harvest and how they interact. These components include the herring stock, natural mortality and predation, the commercial fishing fleet, spawning areas and subsistence harvest areas, spatial attributes like shore type and fetch, and subsistence harvesters. Herring are the principle drivers of the system.

Because herring are a forage fish, the biomass of the stock can be highly variable based on ocean conditions and predation (Hebert 2011). An increase in herring biomass should increase egg deposition levels, which should increase the availability of quality spawning areas. These spawning areas also overlap with key harvest areas. Both areas are constrained by slow variables such as the importance of shore type/substrate and protection from wind and waves. Based on spatial analysis, these critical slow variables have a much greater impact on harvest area site selection than on spawning areas. Finally there are the human actors, the subsistence harvesters and the commercial fishing fleet. The commercial fleet actively harvests surplus herring based on a percentage of the estimated biomass, removing fish from the stock while contributing to various cash economies (Hebert 2011). Subsistence harvesters passively remove eggs from harvest areas as the spawn occurs. Herring roe is a culturally significant resource that is shared not just locally, but statewide and even into parts of the lower 48 (Holen et al. 2011, Thornton 2010). Successfully harvesting roe reinforces the cultural significance of harvest areas through a process that Berkes et al. (2000) describes as the "knowledge-practice-belief complex".

Based on this model, there can potentially be several sources that explain the success or failure of the subsistence fishery. The first would be the biomass of herring, as an increase in biomass would theoretically increase the amount and extent of herring spawn. A second surrogate would be participation in the fishery. In order for needs to be met, people must be out there taking part in the fishery. A final surrogate is the amount of opportunity (or herring spawn) in harvest areas, which can be measured by looking at the number of spawning days. The influence of participation and opportunity will be explored further in Chapter 3.

Figures

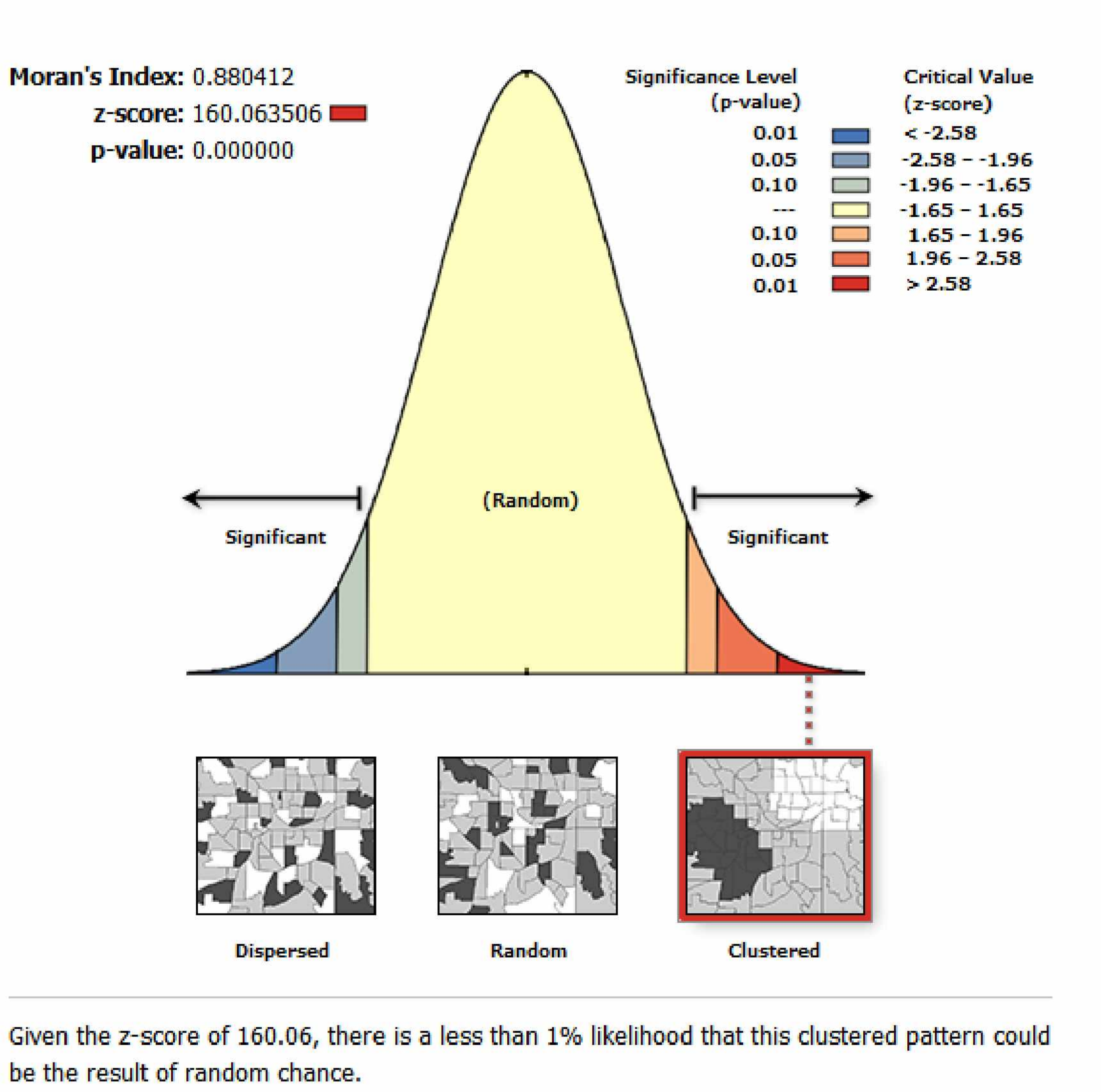


Fig. 2.1 Results of the Global Moran's I test, which measures the clustering of total spawn days across the entire study area for the entire study period (2000 – 2012). A Moran's Index of -1 signifies evenly dispersed values, a value near 0 represents random distribution, and a value of 1 represents completely clustered values.

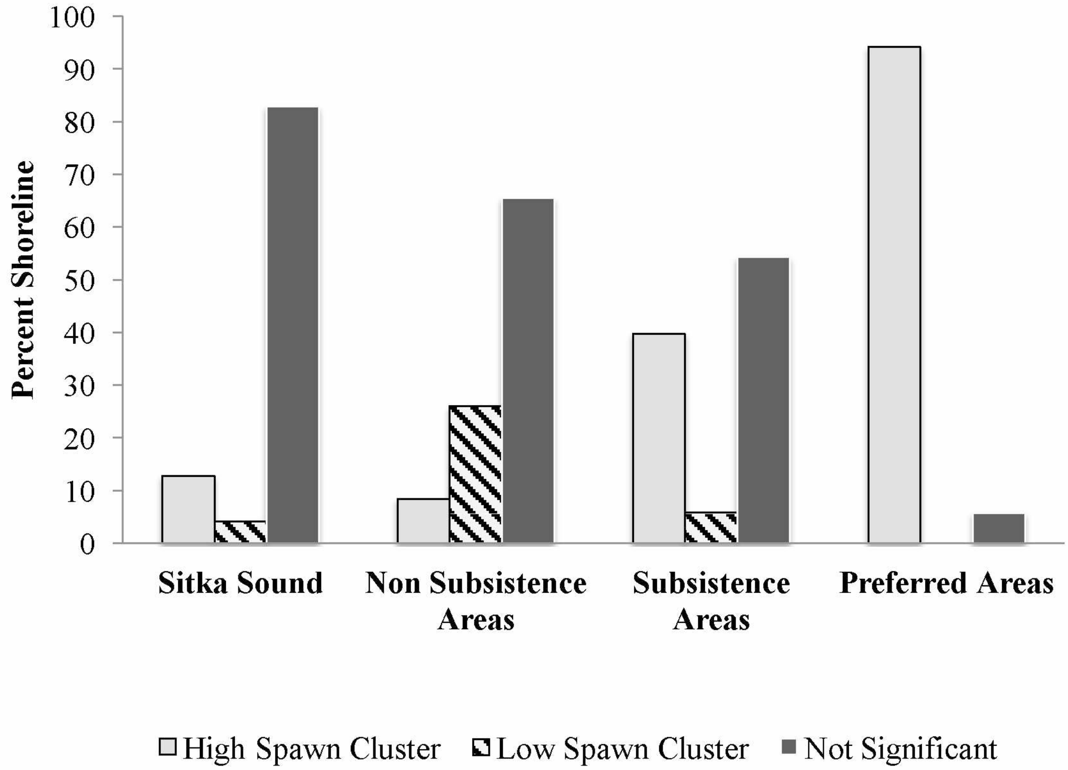


Fig. 2.2 Percentage of shoreline for each spawn cluster type within subsistence use scales.

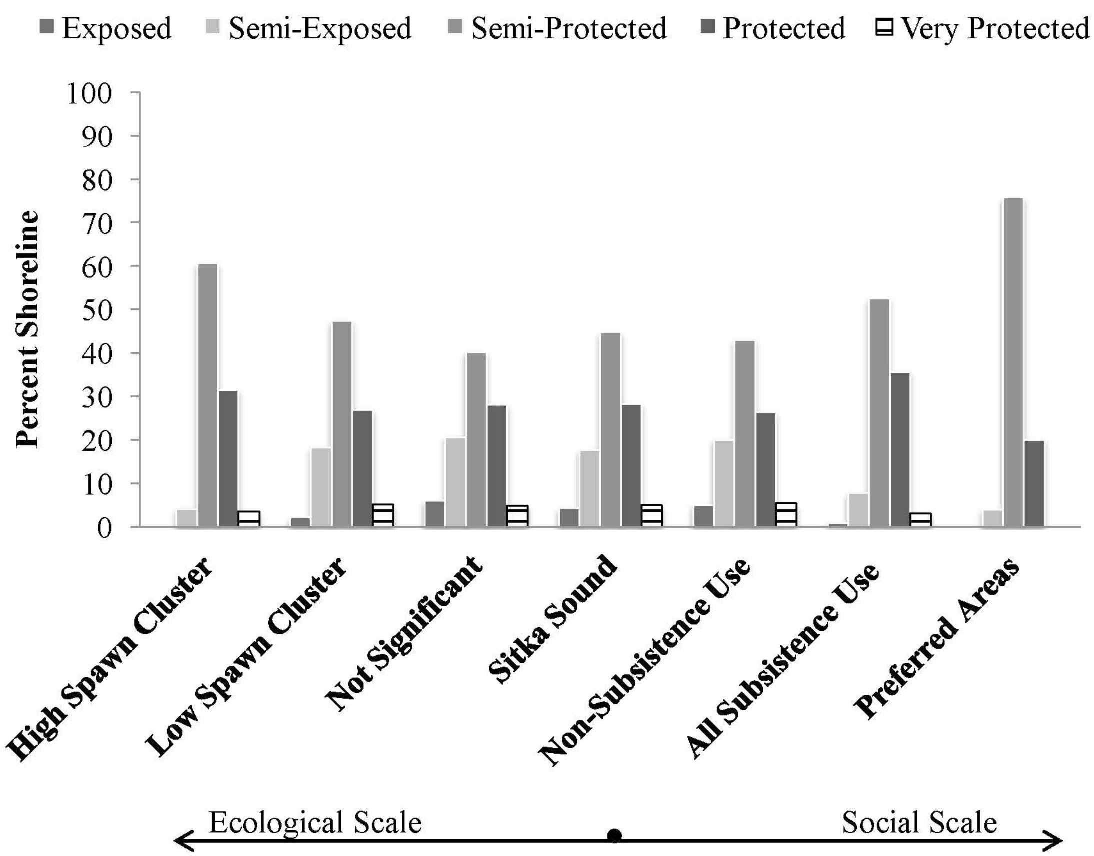


Fig. 2.3 Percentage of shoreline exposure (calculated using NOAA ShoreZone data) at different social and ecological scales. Categories to the left of Sitka Sound represent herring spawn day cluster types (ecological scale). Categories to the right of Sitka Sound represent subsistence use types (social scale).

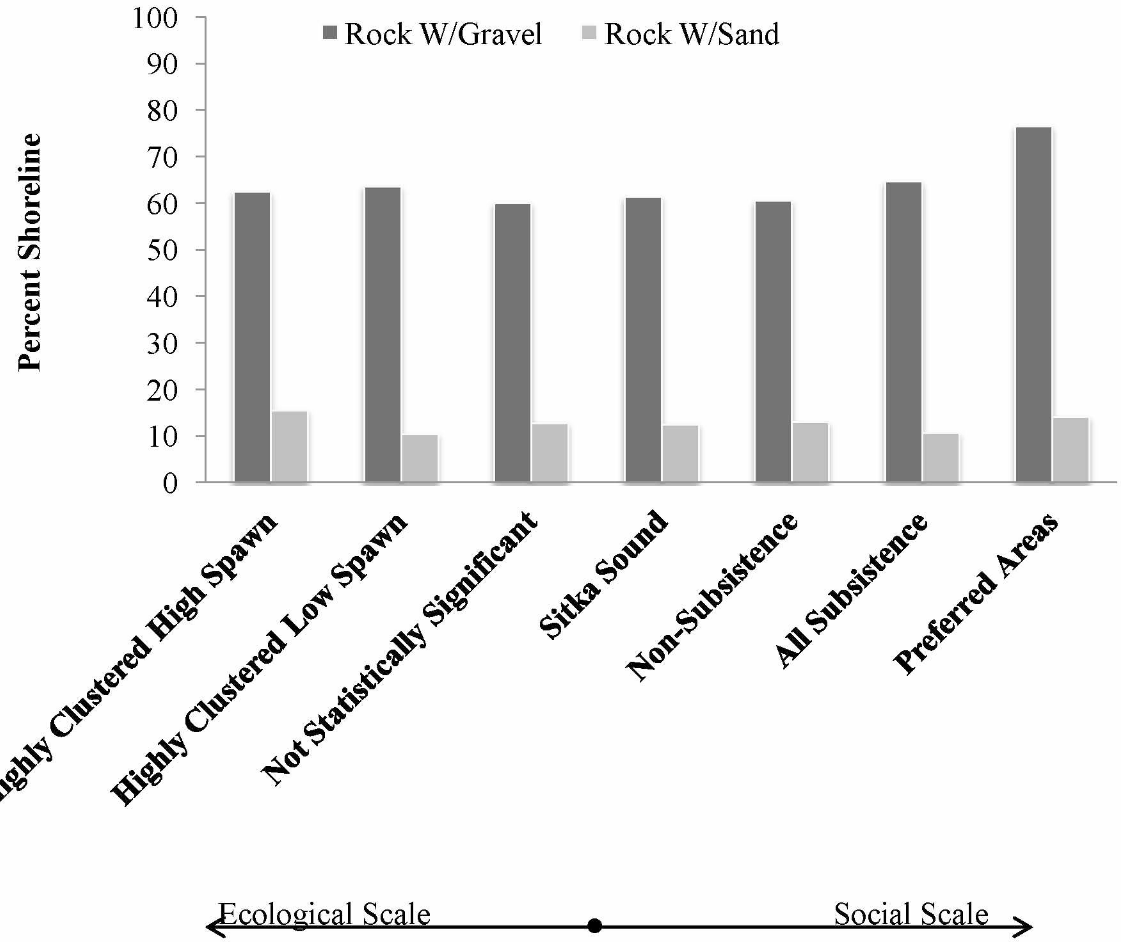


Fig. 2.4 Percentage of shoreline of aggregated shoretype (Rock w/Gravel and Rock w/Sand) across social and ecological scales. Categories to the left of Sitka Sound represent herring spawn day cluster types (ecological scale). Categories to the right of Sitka Sound represent subsistence use types (social scale).

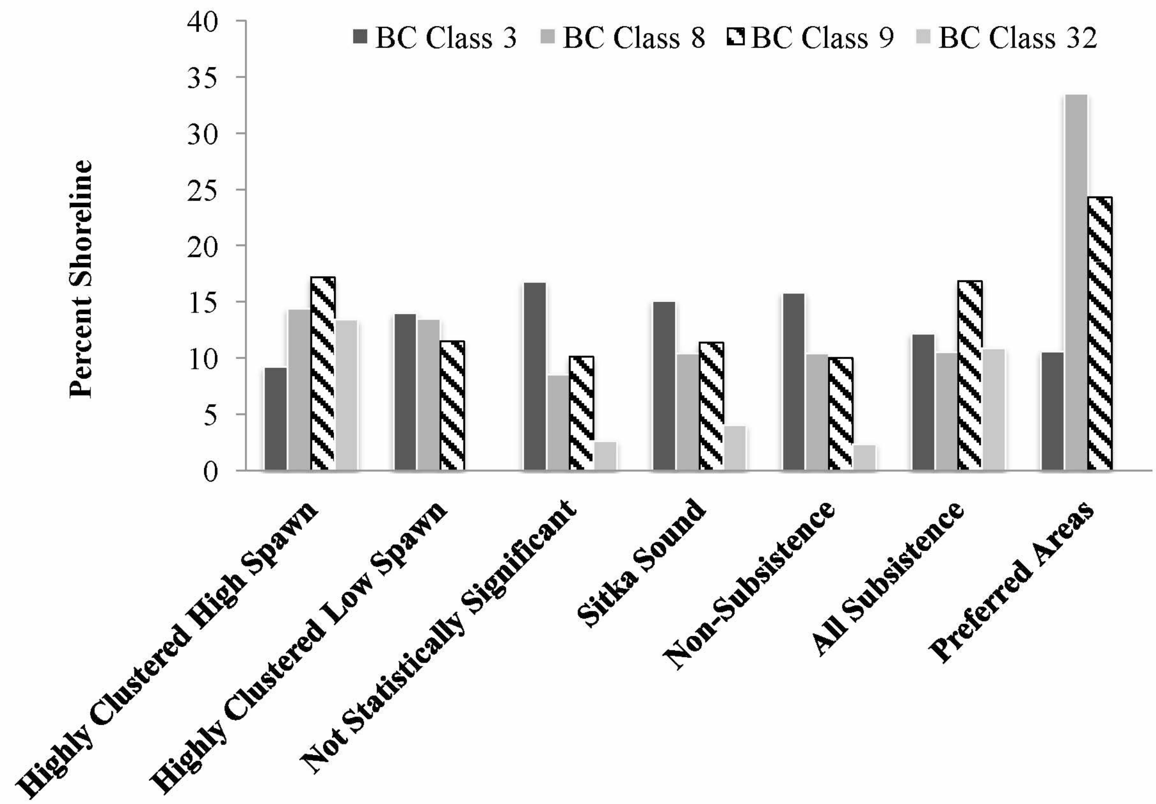


Fig. 2.5 Percentage of shoreline for four dominant shoretypes across social and ecological scales. . Categories to the left of Sitka Sound represent herring spawn day cluster types (ecological scale). Categories to the right of Sitka Sound represent subsistence use types (social scale).

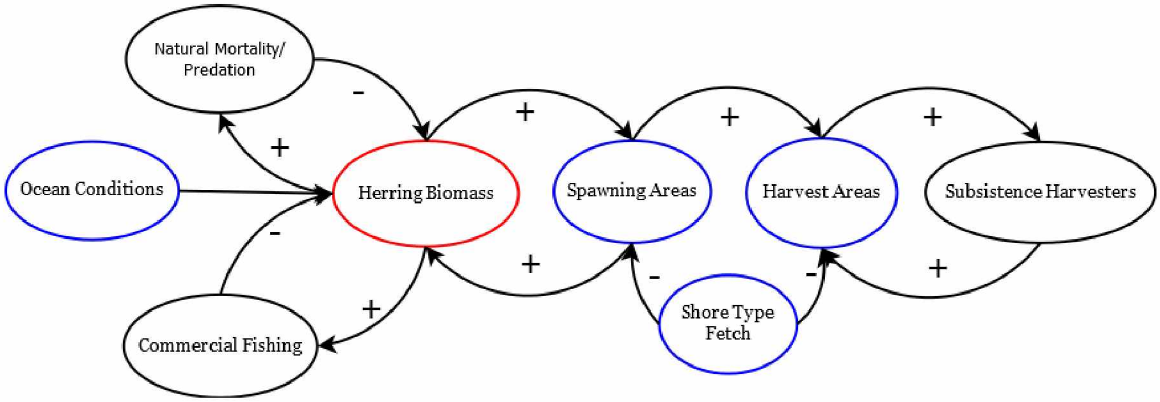
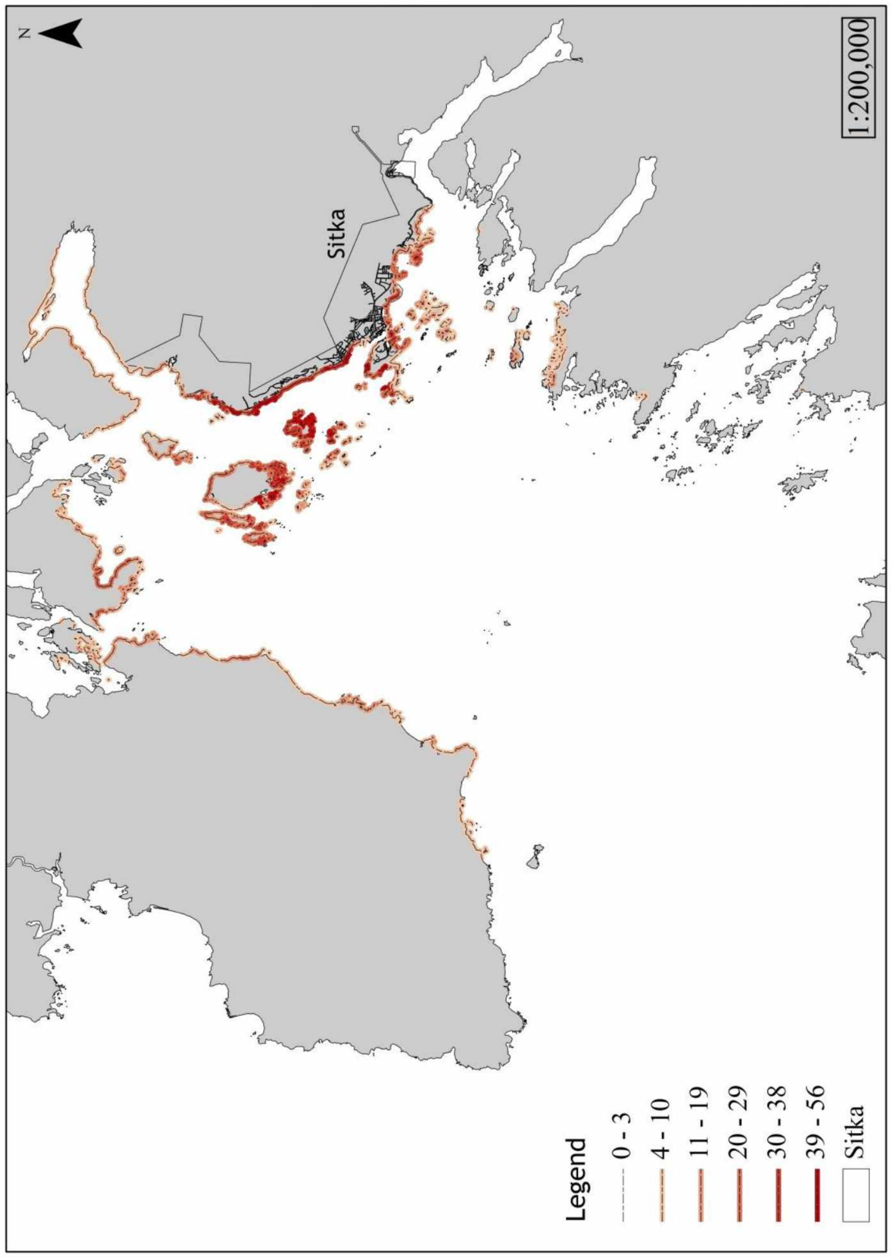


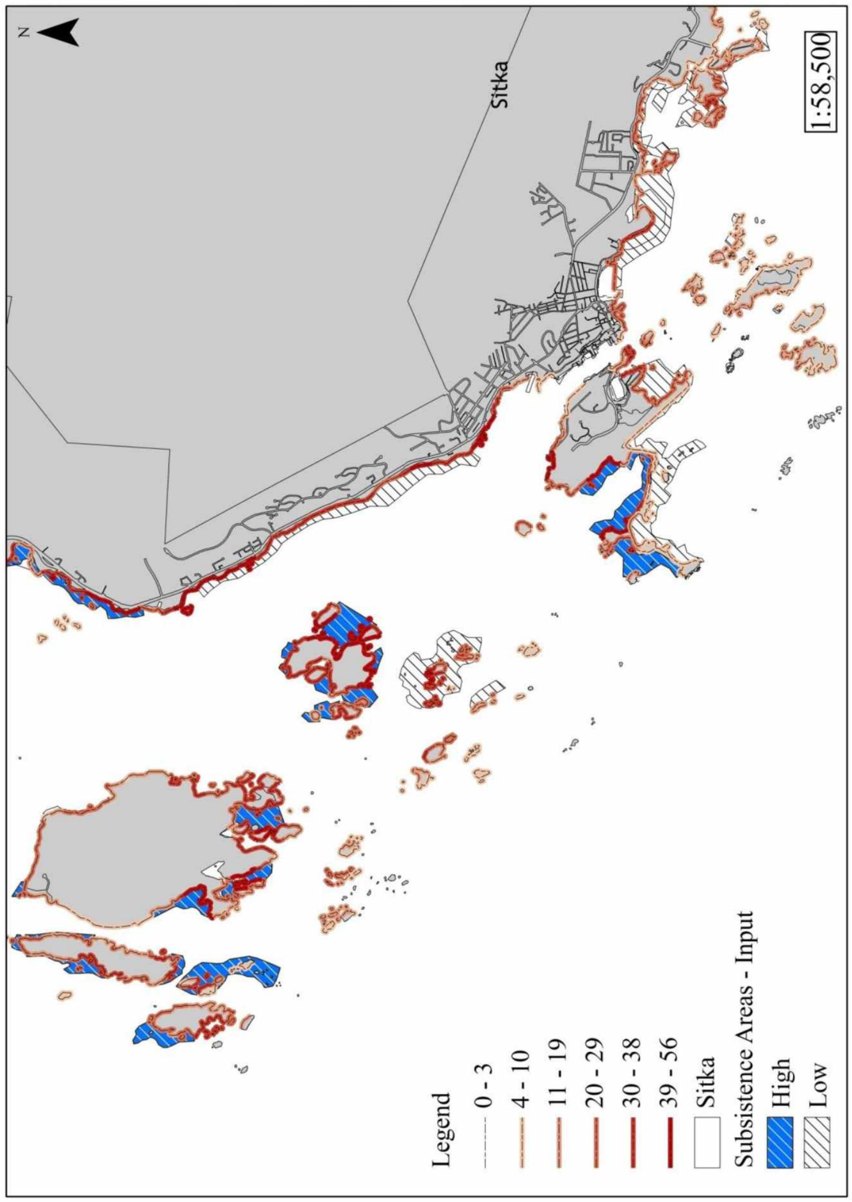
Fig 2.6 Proposed social-ecological systems model for subsistence herring and feedback effects for each component piece.

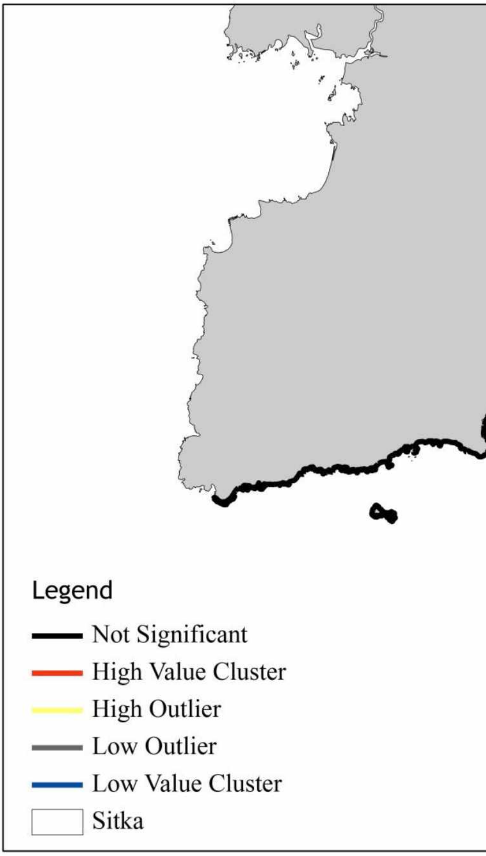
Appendix 2.1 Spawn distribution and cluster analysis maps

Sitka Sound: Spawn distribution (2000-2012)

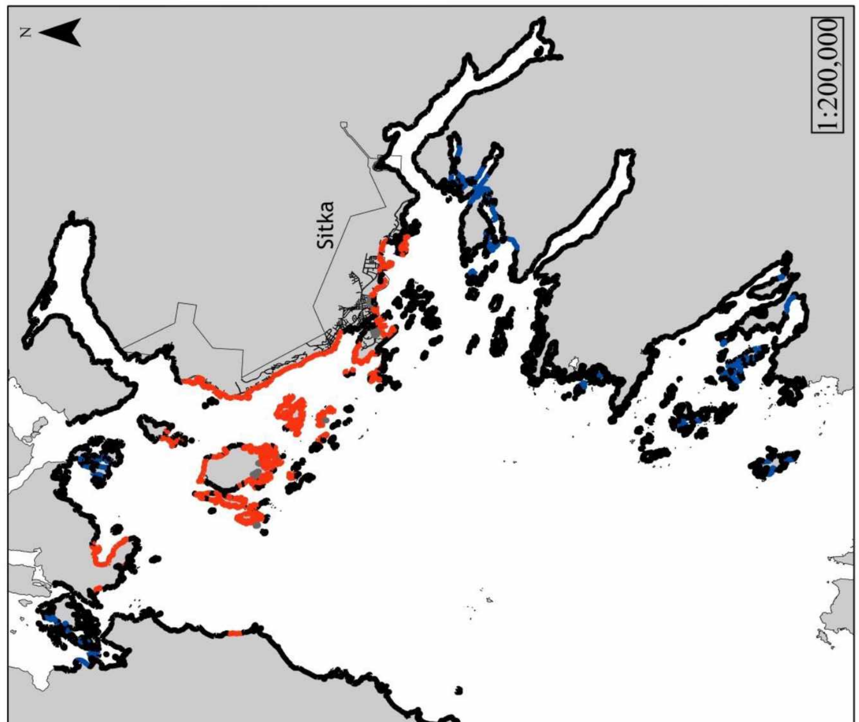


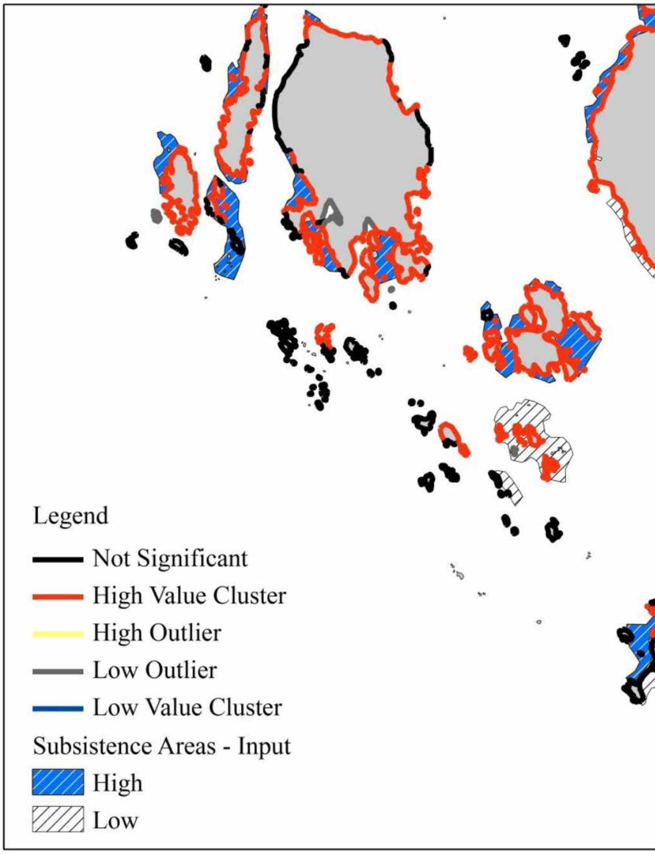
Core Subsistence Area: Spawn distribution (2000-2012)



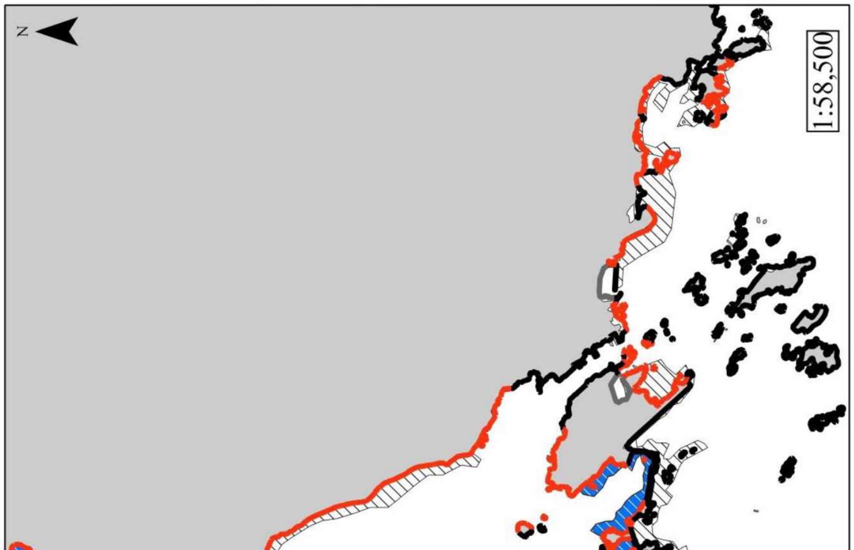

Legend
Not Significant
High Value Cluster
High Outlier
Low Outlier
Low Value Cluster
Sitka

Sitka Sound: Cluster analysis (2000-2012)



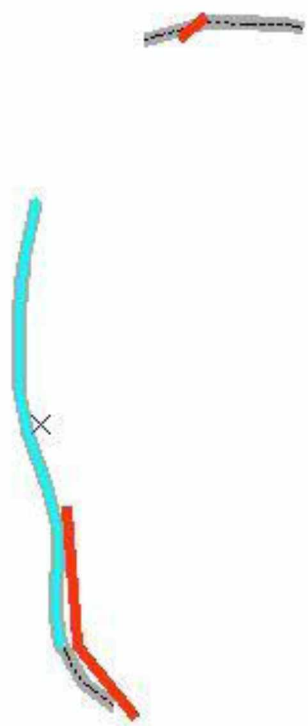

Legend
Not Significant
High Value Cluster
High Outlier
Low Outlier
Low Value Cluster
Subsistence Areas - Input
High
Low

Core Area: Cluster analysis (2000-2012)



Appendix 2.2 ShoreZone editing examples

Example of a shoreline that was excluded because less than half of its length received active spawn.



Example of a shoreline length that was edited out because it only received an isolated stretch of spawn.

Example of annual spawn map for Middle Island. The image on the left is the data collected by ADF&G, the image on the right is after the data was processed, edited, and added to the ShoreZone database. Below is a comparison of data tables, one showing spawn dates, and the other showing counts.

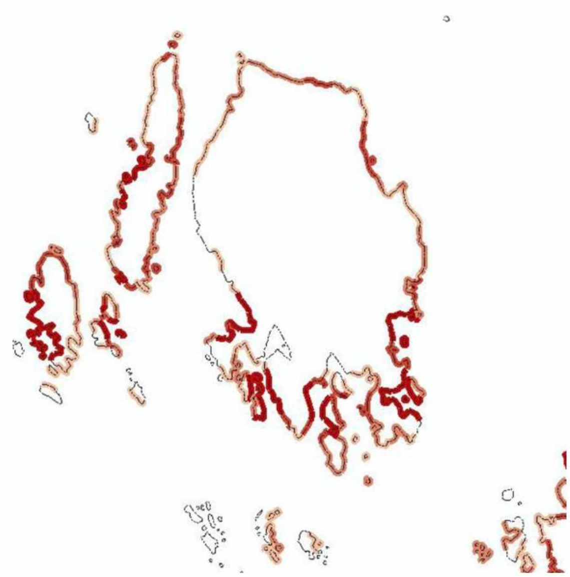


Table - Spawn_Map_2000

Spawn_Count_2000

OBJECTID *	Shape *	OBJECTID_1 *	LENGTH_M	Count_01	Count_02	Count_03
1380	Polyline	60452	145.290341	1	0	0
1381	Polyline	60453	107.558279	1	0	0
1382	Polyline	60454	74.259851	1	0	0
1	Polyline	60393	108.235089	0	0	0
2	Polyline	60395	103.171801	0	0	0
3	Polyline	60396	120.033089	0	0	0

Spawn_Map_2000

OBJECTID *	Shape *	OBJECTID_1 *	LENGTH_M	Spawn_01	Spawn_02	Spawn_03
1380	Polyline	60452	145.290341	03/15/2000	<Null>	<Null>
1381	Polyline	60453	107.558279	03/15/2000	<Null>	<Null>
1382	Polyline	60454	74.259851	03/15/2000	<Null>	<Null>
1	Polyline	60393	108.235089	<Null>	<Null>	<Null>
2	Polyline	60395	103.171801	<Null>	<Null>	<Null>
3	Polyline	60396	120.033089	<Null>	<Null>	<Null>

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CHAPTER 3:

Analyzing Effort in the Sitka Sound Subsistence Herring Fishery: What Drives Success?

ABSTRACT

This paper explores the success and failure of the Sitka Sound subsistence herring fishery by defining and analyzing the component pieces of effort. Effort is an important metric in fisheries management, and properly defining it in a social ecological systems framework is an important step in understanding why subsistence needs are not being met and how that contributes to the resilience of the provisioning service that subsistence herring egg harvests provide. Trends in the participation and opportunity are measured and analyzed separately before being combined into a single joint metric and statistically compared to success (total pounds of eggs harvested).

3.1 Introduction

In order to define success or failure in fishing outcomes, it's important to accurately identify and capture the component pieces that make up effort (Cunningham and Whitmarsh 1980, Squires 1986). Cunningham and Whitmarsh (1980) define effort as "the amount of activity involved in exploiting a fish stock…conceived of either in terms of its impact on the fish population or in terms of the factors giving rise to the activity." The first form of effort is known as *effective* fishing effort, the second is referred to as *nominal* fishing effort.

For commercial fisheries in Alaska, there exists a constitutionally mandated goal for management based on the principal of Maximum Sustained Yield (MSY). MSY allows for a harvesting a surplus of biomass for economic use while preserving enough of the biomass to ensure future harvest (Article 8, Alaska State Constitution). This is an example of *effective* fishing effort, or the extraction of fish as a proportion of population size. While it must still meet the criteria for MSY, the subsistence herring fishery in Sitka is not so much concerned with the proportional extraction of a resource as it is an allocated volume of herring eggs deemed necessary for the continuation of the subsistence lifestyle (Amount Necessary for Subsistence or ANS). The impact of harvesting herring eggs for subsistence is considered to have negligible impact on the survival of the stock of herring and because of regulatory language in the State of Alaska, must be considered as a first priority before any other forms of fishing can be allowed (5 AAC 99.010). Managing for subsistence opportunity thus falls under the category of *nominal* fishing effort. Nominal fishing effort is important, since it does not necessarily need to be linked to stock mortality, it can thus be used as a useful "surrogate" metric for interdisciplinary study and policy analysis (Cunningham and Whitmarsh 1980). In the case of subsistence herring egg harvest, it becomes a surrogate measure for resilience (Bennett et. al 2005), where changes in effort measure the resilience of the provisioning service provided by subsistence herring egg harvest and the ability to meet subsistence needs (Ch. 2). A decrease in effort limits the amount of eggs available for sharing and consumption whereas an increase in effort provides for more of the resource for use and distribution. But before effort can be used as a surrogate for resilience, it (and its principal components) must be defined.

In recent years, the forecasted herring biomass has continually increased (Hebert 2011), yet subsistence harvests have fluctuated wildly. There have been several years in the last decade (2005, 2007, 2008, 2011, 2012) where subsistence needs were not met (Table 3.1 and Fig. 3.1). If the biomass estimates are accurate, then the volume of eggs being deposited in Sitka Sound should also be on the rise. Why then are needs not being met? Here we define "needs" in terms of total lbs of eggs harvested in relationship to the minimum ANS threshold amount. ANS amounts are designed to reflect statewide usage of a subsistence resource and are set following a customary and traditional use (C&T) determination by the Alaska Board of Fish (BOF). A C&T determination for Sitka herring was first made at the February 1989 meeting of the BOF, but the ANS was not set until the January 2002 meeting. The ANS thresholds were originally set at a minimum of 105,000 lbs to a maximum of 158,000 lbs. The original ANS findings were based on data available from three studies done over a decade earlier. In 2009, the BOF increased the thresholds to 136,000 lbs and 227,000 lbs (respectively). Following the 2002 BOF meeting, Division of Subsistence staff began to work with Sitka Tribe of Alaska (STA) to implement the annual household survey program to better capture subsistence needs, participation, and the role and extent of sharing for this resource. This information was used in reevaluating the ANS levels in 2009 (Holen et al. 2011). Because ADF&G – Division of Subsistence captures annual harvest amounts, it is possible to measure success in terms of the ability to meet or exceed minimum ANS thresholds for the last 10 years. This data can be used to analyze effort in terms of participation and opportunity. Decline in participation is often cited as a reason why needs are not met, generally by those supporting the commercial fishery (Sitka Herring Conservation Alliance 2012). However, just as having more fishermen does not necessarily equate to catching more fish, having more households participating in subsistence harvest does not necessarily mean collecting more eggs. There must also be adequate opportunity.

Ethnographic research and spatial analysis has shown that subsistence harvesting of herring eggs is closely tied to particular types of areas (Ch. 2 & 3). It has also shown that herring are somewhat less site specific in where they spawn, meaning that there can be a high level of variability in spatial distribution of herring spawn. Because of the importance of space and variation in spatial distribution, nominal effort must also include some metric of opportunity that involves space. In the case of herring in Sitka Sound, mean spawning days in subsistence harvest areas is a culturally significant metric as well as a statistically accurate one.

Once the principal components of effort are identified, they can then be assembled into a unit of effort. Because subsistence fishing is subject to two primary processes, participation and opportunity, the system falls into what Bennett et. al (2005) describe as a “tipping point” systems model. When participation and mean spawn days are high, subsistence success in the fishery is tied to a larger area. As participation and/or mean spawn days contract, success becomes more closely associated with the most preferred harvest areas. The preferred areas are important because they are well established as being some of the most consistently productive areas in the Sound. These interactions are evident in changes to the fishery since 2008 and 2009. 2008 is considered a critical failure in the fishery by subsistence standards, and 2009 followed a highly contentious BOF cycle where concerns were not adequately addressed. Since then, the preferred areas and the “core” area in general has become a focal point of public debate and policy solutions.

3.2 Effort Analysis

3.2.2 The Role of Participation

A common explanation as to why needs are not being met in the subsistence herring fishery in Sitka is because people simply aren’t participating. This argument came up in particular during the 2013 Board of Fish cycle regarding proposals on the Sitka herring fisheries (Sitka Herring Conservation Alliance 2012). According to ADF&G Division of Subsistence data, during the first three years of the harvest survey (2002 – 2004) an average of 104 households participated in the gathering of herring eggs. Over the last 10 years, that number has steadily declined so that the average participation rate for the last three years has only been 42 households (Holen et al. 2011). This declining trend in participation is represented in Fig. 3.1.

From this chart it would appear that the declining trend in participation and satisfying minimum ANS are closely linked. We can explore this relationship further by using regression modeling (Fig 3.2). When we plot the household participation count as an independent variable predicting the dependent variable of total lbs of eggs harvested, the statistical relationship is significant, but only part of the picture. With an R^2 value of 0.525, participation only explains half of the annual variation in harvest amounts ($P <$ 0.05). There are two important outliers worth pointing out in this analysis. During the 2005 and 2007 harvest seasons, total harvests failed to exceed minimum ANS thresholds in spite of relatively high participation rates (95 and 81 households respectively) further showing that more harvesters does not necessarily equal more eggs.

Even if participation is half the picture, the decline in participation is still an alarming trend. Only 32 households harvested in 2012 compared to the recorded peak participation of 118 in 2004 (Fig. 3.2). Clues as to why participation has declined can be found in qualitative data in the annual survey. Beginning in 2010, the ADF&G annual survey instrument included questions to determine if respondents had harvested in the past, if they harvested in the present, and if they intended to harvest into the future. If they were past harvesters who did not harvest in the current year, they were asked why. In 2010, reasons mentioned by those who did not harvest included: received eggs from the *FV Julia Kae* (a vessel hired by the commercial fleet to harvest and distribute eggs) (24 percent), Working during the harvest (22 percent), personal reasons (health or transportation) (12 percent), not present during harvest (12 percent) and receiving from friends or family (11 percent and 10 percent respectively). Only 4 percent gave no response. Respondents also mentioned in comments that they were combining effort with other harvesters to offset economic costs like fuel price. This is reflected in a decrease across the board for personal consumption and an increase in sharing/receiving (Holen et al. 2011). Similarly in 2011 there were 62 non harvesting households, all but one of which had harvested in past years, and all but two of which planned to harvest in the future. For this year, 22 percent received from family, 19 percent were working, 17 percent lacked a boat, and 14 percent cited health or personal reasons. Receiving from friends, retired from fishing, receiving from STA, and not being present all made up less than 5% respectively (Sill and Lemons 2012).

The discussion on fuel price and economic hardship is an important one, as is the reliance on combined effort. Fuel prices for the study period were not available specifically for Sitka, but for a sample of communities throughout Southeast Alaska.While fuel prices in Southeast Alaska have stayed below the state average, in many communities it has exceeded $8/gallon at times. Between the winter of 2008 and summer of 2009, the regional average price jumped from $3.71/gallon to $4.75/gallon, a 28 percent increase. In 2009 (a relatively good year for egg harvests) prices dropped to a regional average of $3.54/gallon in February. In 2011 and 2012, regional averages were above $4/gallon in January and June (Table 3.2). These high prices can limit not just the number of participants, but the distance traveled and time participants can spend on the water. This could lead to an increased reliance on the nearby islands that constitute the most preferred and core areas of the herring harvest. It also helps explain why households are combining effort as well. It's easier to "chip in" to pay for fuel for someone who has a boat and time to harvest than it is to invest the time and money to harvest for one's own household, particularly when there's uncertainty surrounding how successful an outing might be. As has been mentioned, more harvesters does not necessarily equate to more harvest. In years where there is more opportunity and egg availability, more harvesters are not necessarily needed.

3.2.3 The Importance of Space

If only half of the outcome (total lbs) is based on participation, then that leaves a large amount of variation in harvest left to be explained in our measurement of effort. Opportunity is still unaccounted for. Attributes for opportunity can be found in ethnographic data on the fishery (Ch. 1) as well as in policy proposals put forth by Sitka tribe as a way of protecting their subsistence rights (Alaska Board of Fish Proposals Index 2012). Namely, herring have to spawn for multiple days in areas that are conducive to subsistence fishing (Thornton et al. 2010, Research interviews). This is an important point because the State of Alaska can't manage participation per se, but it is obligated to provide "reasonable opportunity" for subsistence activities (5 AAC 99.010). Since it has no direct control over participation, being able to define a metric for opportunity and developing management goals to maximize such a metric are important in providing for subsistence needs.

Using a GIS database, several metrics were calculated at various scales to measure the effects of herring spawn days on success. The principal metric for this was mean spawn days. This metric was calculated by tallying up the total number of spawning days for shore line segments, and dividing by the total number of shore line segments. This could be done for all of Sitka Sound, subsistence only harvest areas, non-subsistence areas, and the most preferred subsistence harvest areas. For this project, spawn days in subsistence areas and preferred harvest areas are emphasized, since those socially constructed geographic scales are the most important to harvesters (Ch 1). Fig. 3.3 and 3.5 show trends in spawning days at both scales.

For subsistence area spawn days (Fig. 3.3), the moving average trend line closely follows the trend line for total pounds harvested up until 2009. After 2009, the mean spawn days jump to higher levels but harvests remain low. If we model this relationship using mean spawn days as a predictor of success (total lbs harvested) for the entire study period, we get a regression model with an R^2 value of 0.326 with a $P < 0.1$ (Fig. 3.4). However when we look at Fig. 3.3, we see that there has been a significant change in the relationship of the two variables since 2009. If we run the same linear model on the data just for 2002 through 2009 we get a much stronger statistical relationship, with an R^2 of 0.859 ($P < 0.001$). The difference in the two models (Fig. 3.4 vs Fig. 3.5) supports the idea that in the years following 2009, the spatial relationship between subsistence harvesters and success has changed. Fig. 3.5 shows the same linear regression split out into the two temporal categories, the first being from 2002 to 2009, and the second from 2010 to 2012. It's hard to place a lot of significance on the relationship in the last period

($P < 0.5$) as there are only three data points. If the spatial relationship has changed, one possibility is that people are relying more on the preferred harvest areas than before, which would explain why these areas have become the focus of the policy debate.

Fig. 3.6 shows mean spawn days in the most preferred subsistence areas (point plot) versus the annual harvest in relationship to the minimum ANS threshold. The chart shows that there are similarities in the moving trend lines for change in harvest and change in mean spawn days, with a major shift occurring again after the 2009 harvest year. Fig. 3.7 is the linear regression model for mean spawn days in the preferred subsistence areas as a predictor of total lbs harvested. The R^2 is 0.409 ($P < 0.05$).

Once again, splitting the predictor variable into two different time frames changes the relationship substantially. Fig. 3.8 shows that mean spawn days in preferred areas predict total pounds harvested with an R^2 of 0.712 ($P < 0.01$) from 2002 to 2009, and with an R^2 of 0.963 ($P < 0.5$) for the last three years in the study period. More data is needed in the years to come to verify what the current relationship is between preferred areas and the success of the fishery, and how that has changed since 2009, but the data so far supports the hypothesis that the system has shifted into an altered state. Since 2009, it seems that spawning days in preferred areas are more effective at predicting harvest, although more data points are needed. What exactly has caused this shift is hard to identify. It could be related to the failure of the 2008 fishery or social processes related to the 2009 BOF cycle.

Using GIS, other metrics can also be calculated to analyze the fishery. Table 3.1 shows the total shoreline (km) that received three or more days of active spawn. The three day mark is often mentioned in ethnographic accounts as being the minimum threshold for reasonable opportunity (Thornton et al. 2010, personal correspondence). The lengths are divided into three spatial categories: non-subsistence areas (Category A), subsistence harvest areas (Category B), and preferred harvest areas (Category C). Ratios were calculated between the three for each year. Low harvest years (below the minimum ANS) are shaded grey for emphasis. The most important aspect of this table is the ratio of shoreline receiving three or more days of spawn. In ethnographic accounts, 2008 is often cited as a "critical failure" year in the subsistence fishery, in spite of the fact that the commercial fishery took in 14,386 tons of herring (ADF&G Commercial Herring Fisheries Website 2013).

The reason this year was such a failure for subsistence can be seen in the total kilometers of spawn, the ratio for spawn in non subsistence areas compared to subsistence areas (A:B), and the ratio for non subsistence areas to preferred areas (A:C). Subsistence areas only had 3.96 kilometers of shoreline with 3 or more days of spawn, and the preferred areas only had 1.86 kilometers. Shoreline outside of subsistence use areas received nearly 7 times that amount when compared to subsistence areas and 14 times that of the preferred areas. All of these values are well outside the mean for the study period. This extreme event also coincides with the change in the relationship of mean spawn days to harvest success and the 2009 BOF cycle (which occured just before the beginning of the 2009 fishing season). The 2009 board cycle saw an increase in proposals and public testimony relating to regulations affecting subsistence and commercial herring fishing in Sitka (ADF&G Board Support 2012, personal correspondence).

3.2.4 Building Better Metrics

Finally, after analyzing each of these individual pieces as a component of success in this fishery, the pieces can be assembled to make a whole. Effort is often described as a joint metric of participation (for example, number of vessels, amount of gear or equipment) and opportunity (soak time, distance or area covered). While effort is useful in understanding the pieces that make up a successful fishery, it seems underutilized in subsistence fisheries in that it is seldom ever calculated or reported. This could be due to the fact that the types of gear used, even within a single fishery, can be highly variable. In the herring fishery, some households make sets that include several trees tied together in a long skate, some make sets using a single tree, and in some cases sets can simply be a group of branches tied together (Ch. 1). Capturing accurate gear level data for individual harvesters can also be incredibly difficult and invasive when working with a social group that is often skeptical about providing detailed information, even when the data is protected and handled to maintain confidentiality and anonymity. An additional challenge comes from the fact that some harvesters share boats and sets with family and friends. ADF&G Division of Subsistence has been incredibly successful over the years in capturing data at the household level, including information on participation, location, and total amounts harvested, gifted, and received (Holen et al. 2011).

This data has already proven useful in analyzing how household participation impacts success in a way that is statistically significant, even if it's only half the picture.

The next step is to expand the measurement of effort to include the influence of time and space, both of which are important from a social-ecological perspective. Based on ethnographic research, resilience modeling, and spatial analysis, the two leading candidates for accomplishing this are mean spawn days in subsistence harvest areas and mean spawn days in preferred harvest areas. By multiplying participation (number of households harvesting within a given year) with mean spawn days for both geographic scales, a new metric is derived referred to from here on out as “household days”. This formula is consistent with effort measurements used in other fisheries, such as the boating days (# of boats times # days in fishery) metric used in the Taku River commercial gillnet fishery. Household days for all subsistence areas and just the preferred harvest areas were then calculated and compared to harvest outcome (total pounds of herring eggs harvested in a given year). These plots can be seen in Fig. 3.9 and 3.10.

Both metrics capture a large portion of the variability in total harvest in the fishery and are statistically significant ($P < 0.001$). Interestingly enough, household days for all subsistence areas explains a greater amount of variability at a greater level of significance than household days for preferred areas. This is likely due to the fact that certain areas in subsistence harvest areas (outside of the preferred areas) only receive spawn sporadically from year to year. As an example, in 2010 there was a large spawn event near Silver Bay at Whale Cove, and many people took advantage of that event to harvest areas near the road system (Holen et al. 2011). While people may seek out spawn in the most preferred areas first (Ch 1), if substantial spawn occurs in areas conducive to setting branches, harvesters will generally seek out those areas and make sets there as well. This measurement of effort captures that spatial variability within subsistence areas and appears to be accurate throughout the entire study period.

3.3 Conclusions

Constructing a culturally meaningful and statistically significant metric for effort is a large step in understanding the spatial resilience of the SES for subsistence herring fishery. Capturing the importance of participation and opportunity in a single metric highlights the importance of both in providing reasonable opportunity in the subsistence herring fishery. While participation is important to success, more harvesters doesn't necessarily mean greater success, and in some cases a small number of harvesters are surprisingly successful in collecting a large amount of eggs. The success of any given harvester is also influenced by the amount of spawn in areas conducive to the setting of branches or cutting of kelp. It's already been demonstrated that harvesters put more effort in certain "preferred" areas. These areas are generally places that are safe to access and consistently productive year to year (Ch. 1). More importantly, any subsistence area (preferred or otherwise) must receive multiple days of spawn in order to build up "quality" egg deposition. More eggs mean more weight, which makes reaching and exceeding the ANS level easier. For these reasons, mean spawn days in subsistence areas are an important component in measuring effort.

Because success is tied to both participation and opportunity, the SES can be described as a "shifting threshold" system. As participation and opportunity at a broader scale decline, effort collapses into a smaller geographic space typified by the most preferred harvest areas. These places represent an area in Sitka Sound where the chance of success is highest as they are the most consistently productive (Ch 2). Because of this, they are a focal point in the fishery. This dependence decreases resilience by “putting too many eggs in one basket”. The ideal scenario for resilience in the subsistence herring fishery is one where participation is stable and opportunity allows for those harvesters to spread out over a wider space, providing more opportunity and thus increasing chances of success in the fishery. This “household days” metric not only reflects cultural and biological significance, its statistically significant and effective at explaining variations in annual harvest amounts for the entire study period. While policy makers and managers can’t directly affect participation, acknowledging and understanding the significance of the spatial distribution and intensity of spawn could lead to better ways of managing the shared space in which both the commercial and subsistence fisheries take place.

Even though herring tend to favor certain areas when they spawn, there can still be a wide range of variability in spatial distribution from year to year. It’s uncertain what drives that variability. Whether its water temperature, currents, or commercial fishing pressures, more work needs to be done to explain outlier years like 2008, so that any human impacts can be minimized to protect subsistence rights. The main reason for minimizing impacts to herring spawn distribution is due to the fact that subsistence harvesters are connected to the spawn through very specific spots, and are therefore less resilient to large scale shifts in spawn distribution. In order to uphold its subsistence priority and create reasonable opportunity for subsistence herring egg harvest, the State of Alaska and ADF&G must be sensitive to human induced factors (such as commercial fishing) that may disrupt spawn distribution in these areas.

Tables

Table 3.1 Comparison of total shoreline (km) receiving 3 or more days of active spawn. Shaded years represent years where minimum Amount Necessary for Subsistence (ANS) thresholds were not met.

A = Non Subsistence Areas, **B** = Subsistence Areas, **C** = Preferred Subsistence Areas

Year	A	B	C	A:B	A:C	B:C
2000	29.20	54.39	12.60	0.54	2.32	4.32
2001	16.49	18.41	4.10	0.90	4.02	4.49
2002	27.36	32.15	6.02	0.85	4.55	5.34
2003	31.84	26.41	13.75	1.21	2.32	1.92
2004	37.86	41.24	11.29	0.92	3.35	3.65
2005	24.00	11.64	3.98	2.06	6.04	2.93
2006	31.95	23.71	11.60	1.35	2.76	2.04
2007	12.11	14.06	2.84	0.86	4.27	4.96
2008	26.65	3.96	1.86	6.72	14.33	2.13
2009	17.56	18.52	9.34	0.95	1.88	1.98
2010	42.18	37.76	12.52	1.12	3.37	3.01
2011	33.91	32.99	9.06	1.03	3.74	3.64
2012	22.94	15.72	7.20	1.46	3.19	2.18
Mean	**27.23**	**25.46**	**8.17**	**1.54**	**4.32**	**3.28**
St. Dev	8.64	13.90	4.10	1.60	3.20	1.21
Mean	**27.28**	**27.25**	**8.69**	**1.10**	**3.48**	**3.37**
St. Dev (w/o 2008)	9.02	12.86	3.79	0.39	1.15	1.21

Table 3.2 Fuel price ($/gallon) trends for Southeast Alaska from 2005 to 2012. Percent Change represents the change in the average price of fuel relative to the prior sample period average.

Sample Month	Average	% Change	High	Low
Nov 2005	3.29	N/A	4.15	2.76
Nov 2006	3.41	3.81	4.25	2.65
Jun 2007	3.75	9.80	4.32	3.1
Nov 2007	3.71	-1.04	4.08	3.31
Jun 2008	4.75	28.11	5.5	4.19
Oct 2008	5.10	7.38	8.8	3.64
Nov 2008	4.71	-7.64	8.8	2.89
Feb 2009	3.54	-24.96	8.8	2.2
Jun 2009	3.65	3.29	8	2.71
Jan 2010	3.60	-1.44	4.5968	3.1058
Jun 2010	3.95	9.72	4.68	3.25
Jan 2011	4.15	5.04	5.1792	3.4026
June 2011	4.87	17.43	6.0112	4.1265
Jan 2012	4.70	-3.51	5.96	3.999
Jul 2012	4.70	0.00	5.96	3.999

Source: Alaska Division of Community and Regional Affairs, Research and Analysis Section

Figures

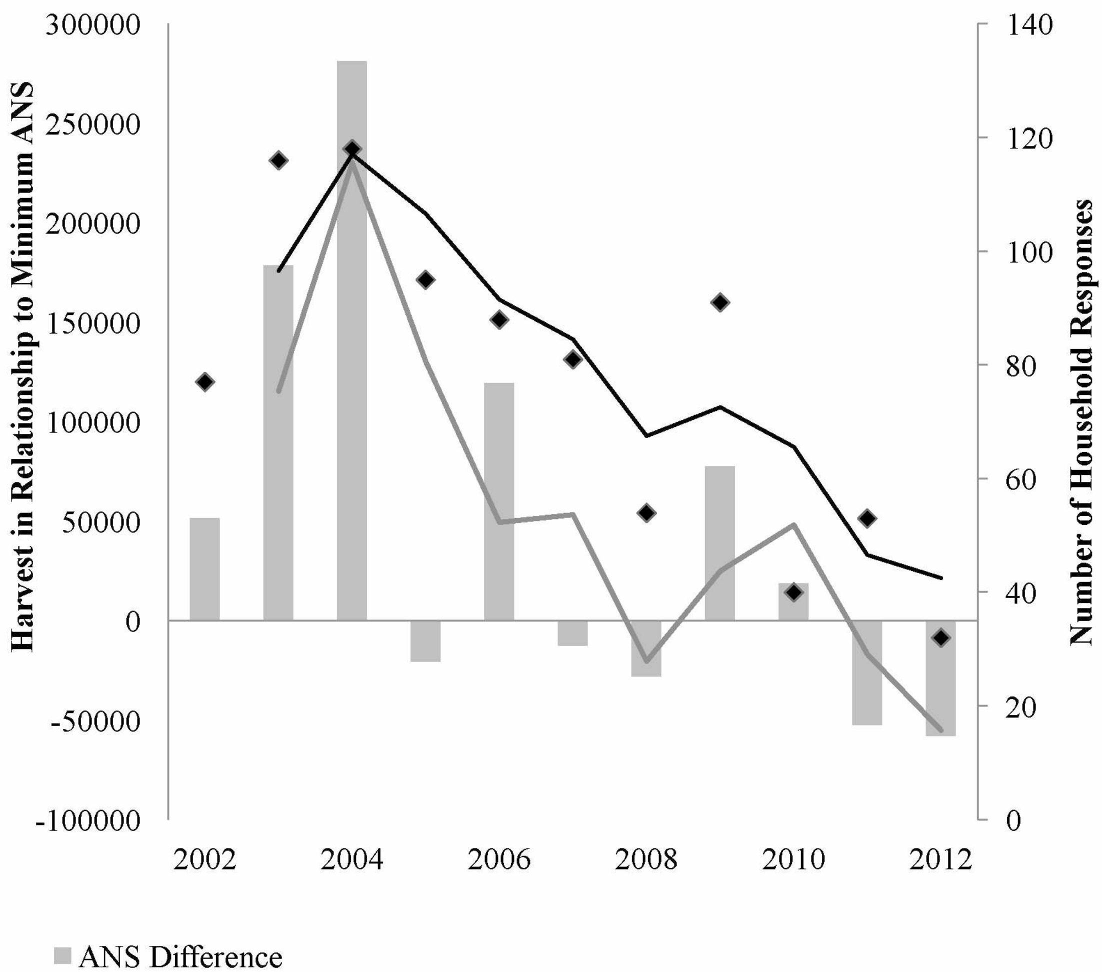

Fig. 3.1 Annual harvest amount (in relationship to the minimum Amount Necessary for Subsistence or ANS) and participation in the fishery as measured by ADF&G annual surveys. Points on the graph represent the reported household participation rates from the annual ADF&G survey, the bar chart represents the total amount of eggs harvested in relation to the minimum ANS threshold (105,000 lbs up until 2008 and 136,00 lbs starting in 2009) the two trend lines represent a two year moving average for both participation (black line) and the ability to meet or exceed the minimum ANS during the survey period (grey line).

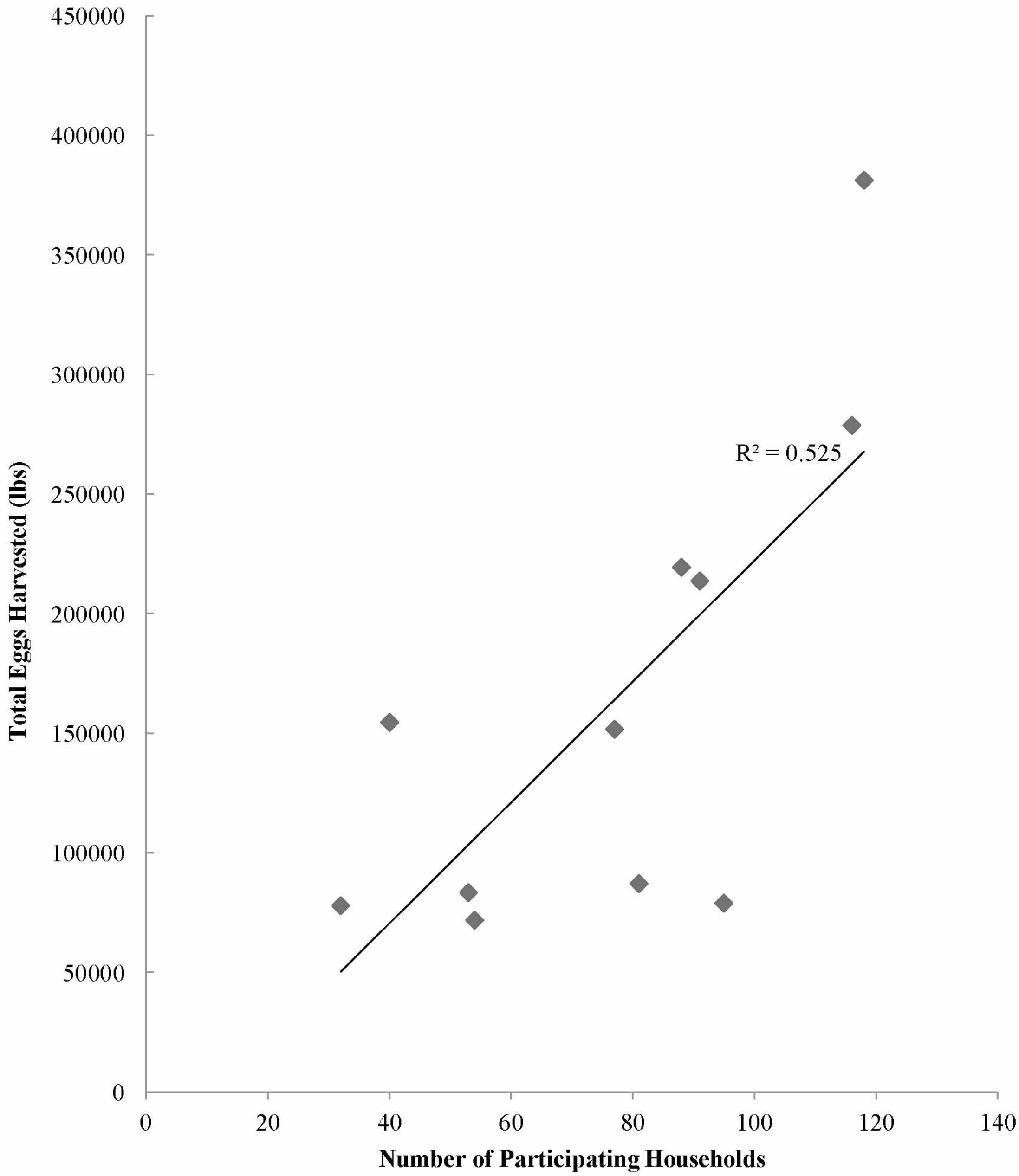

Fig. 3.2 Annual household participation in subsistence herring fishery vs. total annual subsistence harvest (lbs eggs). (from the ADF&G annual survey data)

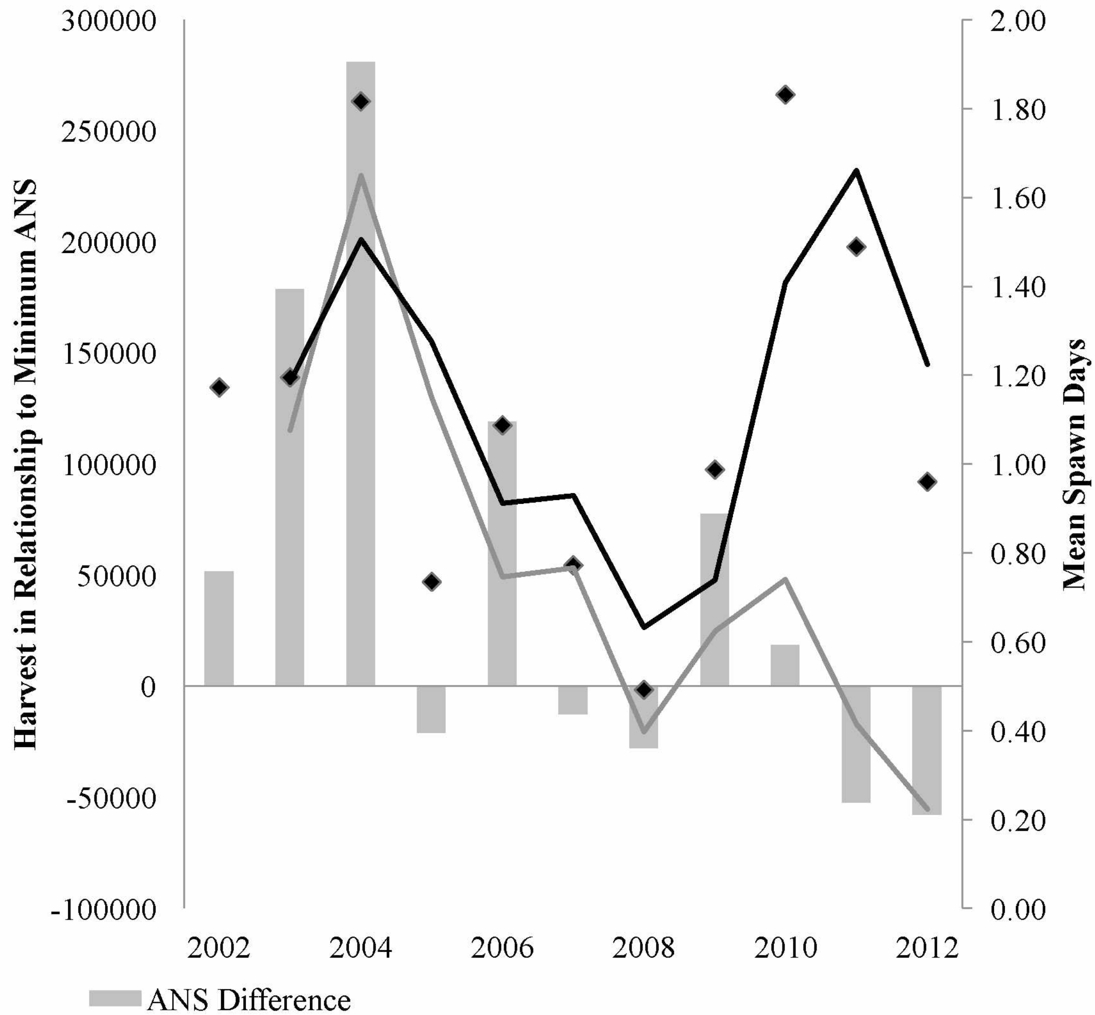

Fig. 3.3 Annual harvest amount (in relationship to the minimum Amount Necessary for Subsistence or ANS) and the average number of spawning days in subsistence harvest areas. Points on the graph represent the mean spawn days, the bar chart represents the total amount of eggs harvested in relation to the minimum ANS threshold (105,000 lbs up until 2008 and 136,00 lbs starting in 2009) the two trend lines represent a two year moving average for both spawn days (black line) and the ability to meet or exceed the minimum ANS during the survey period (grey line).

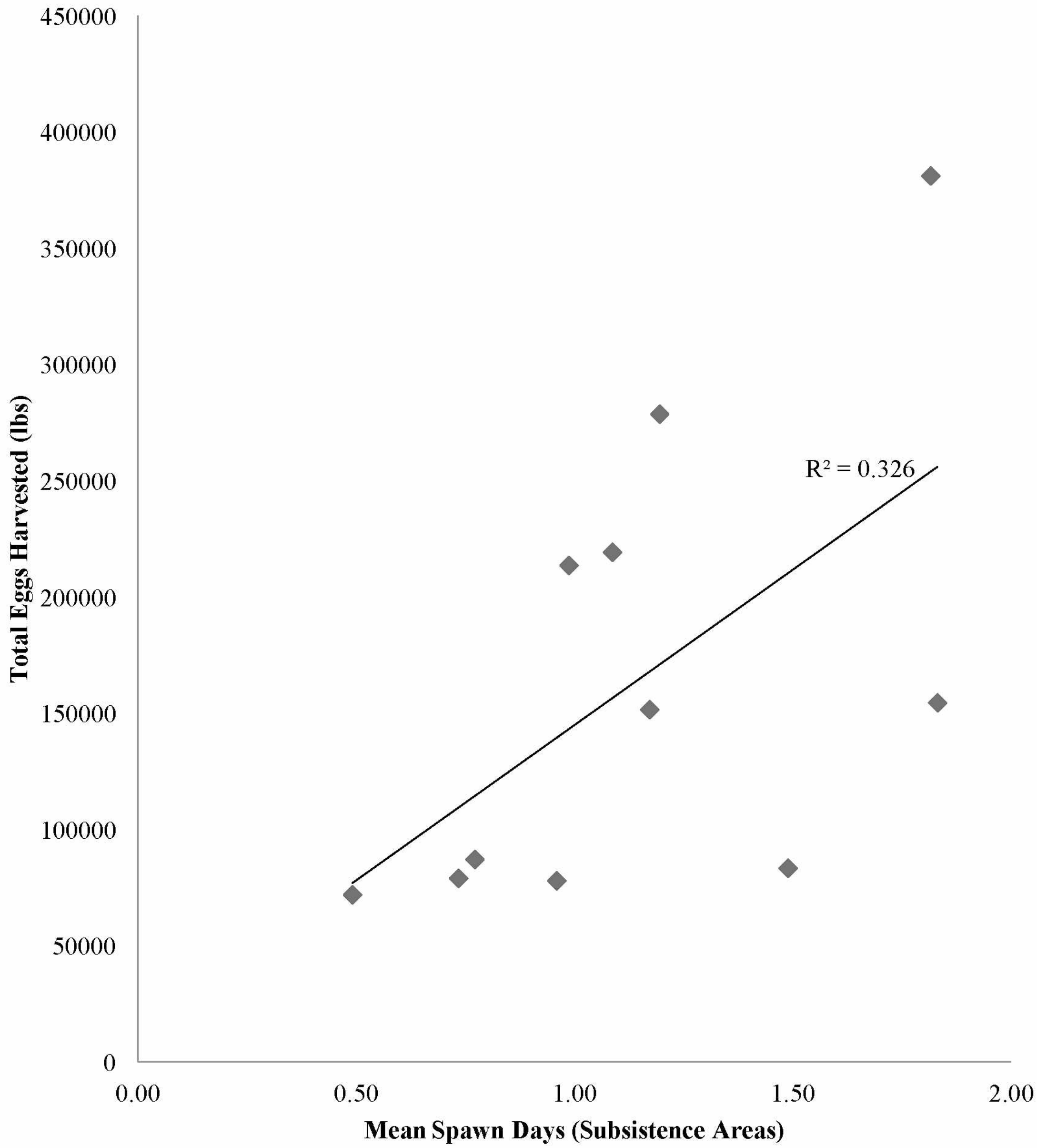

Fig. 3.4 Mean number of spawning days in subsistence areas vs. total annual subsistence harvest (lbs eggs)

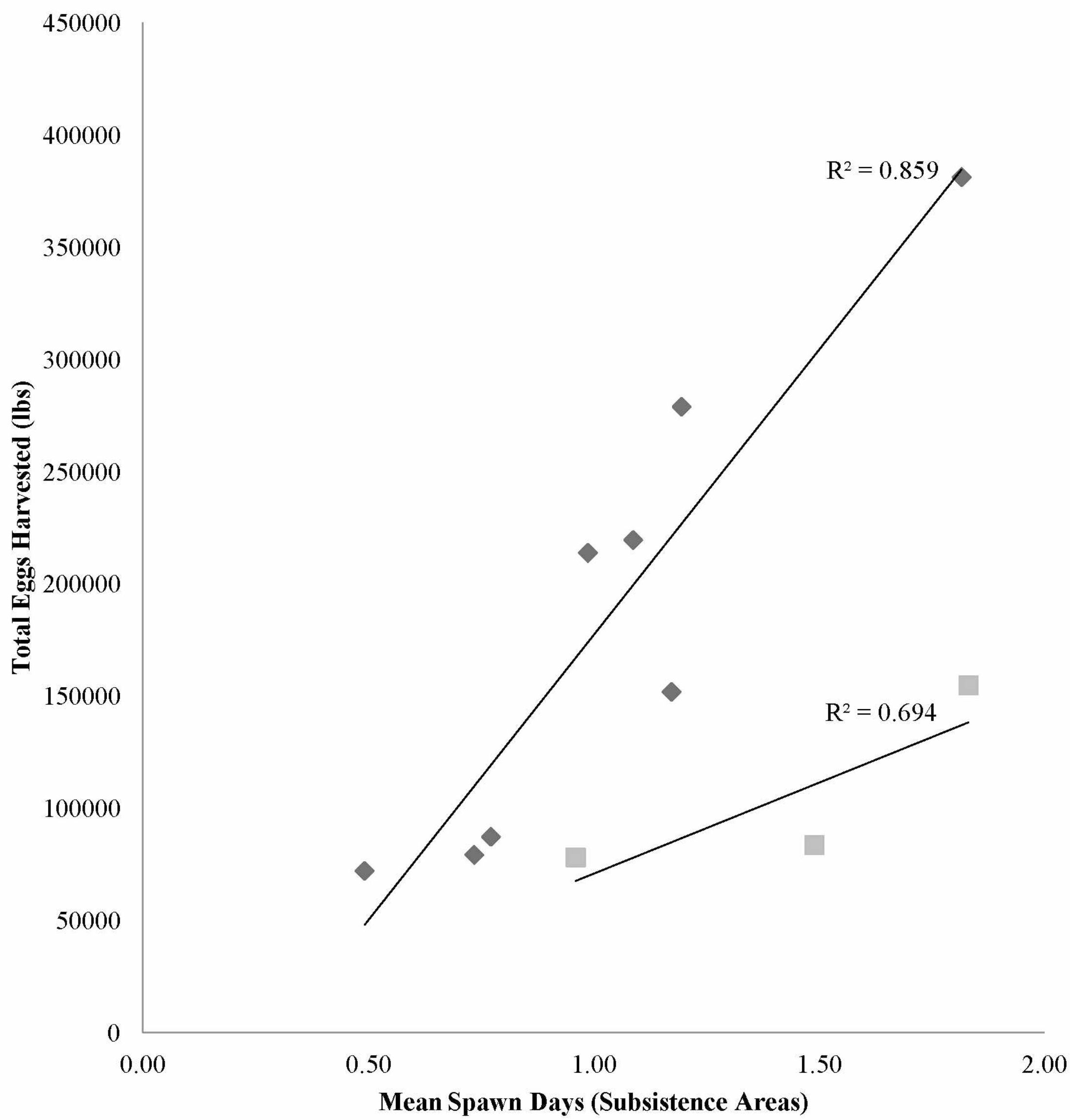

Fig. 3.5 Mean number of spawning days in subsistence areas vs. total annual subsistence harvest (lbs eggs). Trend lines are broken out into two time periods, 2002-2009 and 2010 to 2012.

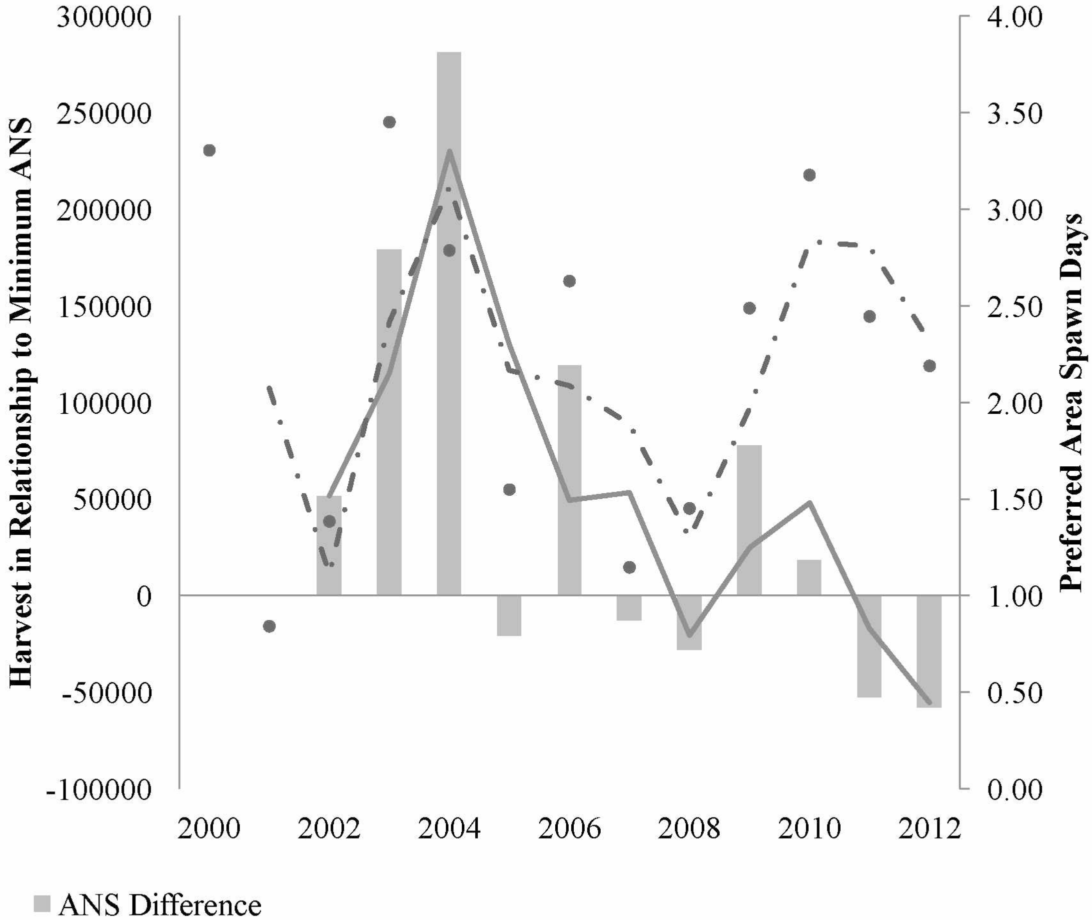

Fig. 3.6 Annual harvest amount (in relationship to the minimum Amount Necessary for Subsistence or ANS) and the mean number of spawning days in the preferred harvest areas. Points on the graph represent the mean spawn days, the bar chart represents the total amount of eggs harvested in relation to the minimum ANS threshold (105,000 lbs up until 2008 and 136,00 lbs starting in 2009) the two trend lines represent a two year moving average for both spawn days (grey dotted line) and the ability to meet or exceed the minimum ANS during the survey period (grey solid line).

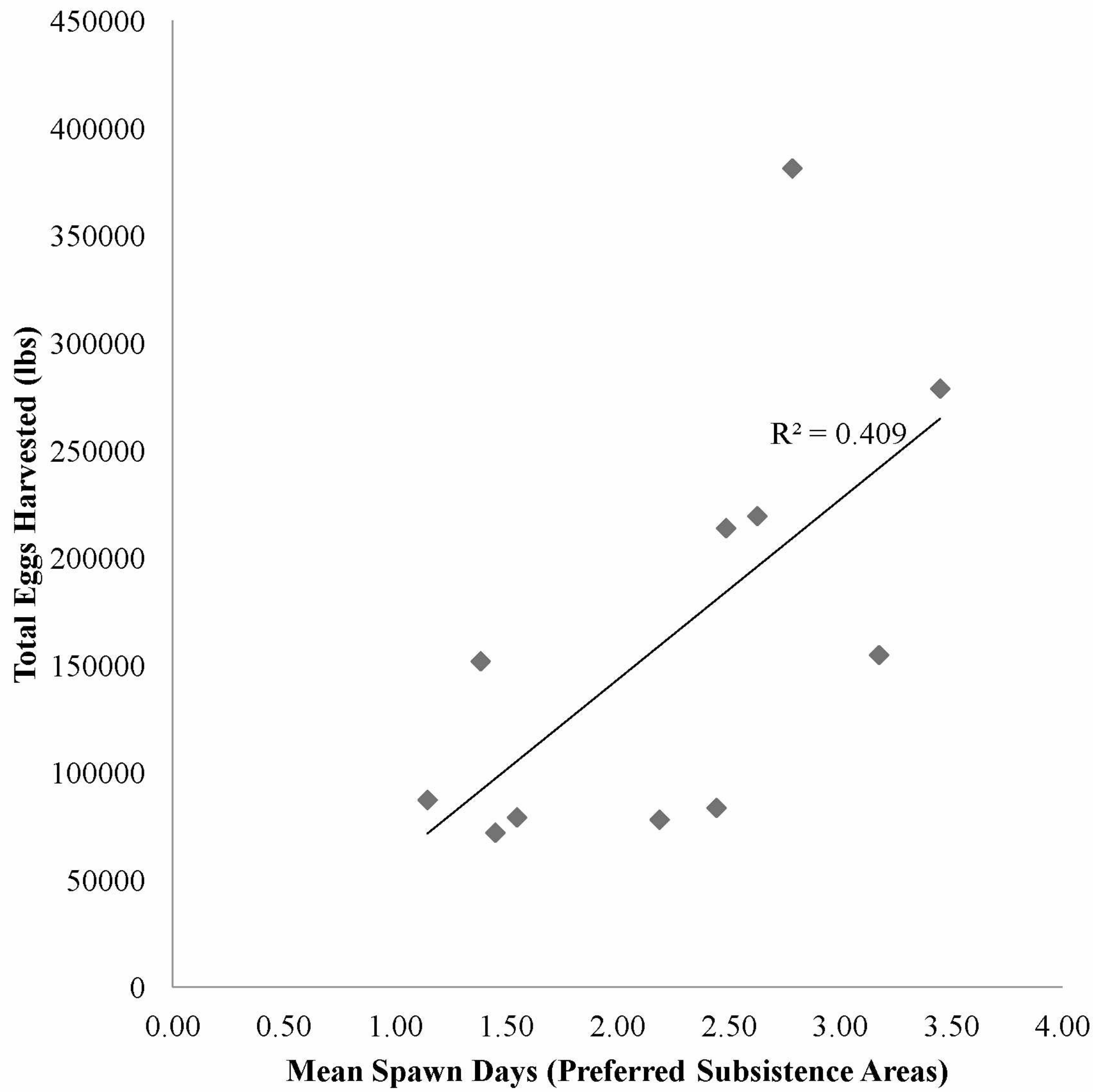

Fig. 3.7 Average number of spawning days in preferred subsistence areas vs. total annual subsistence harvest (lbs).

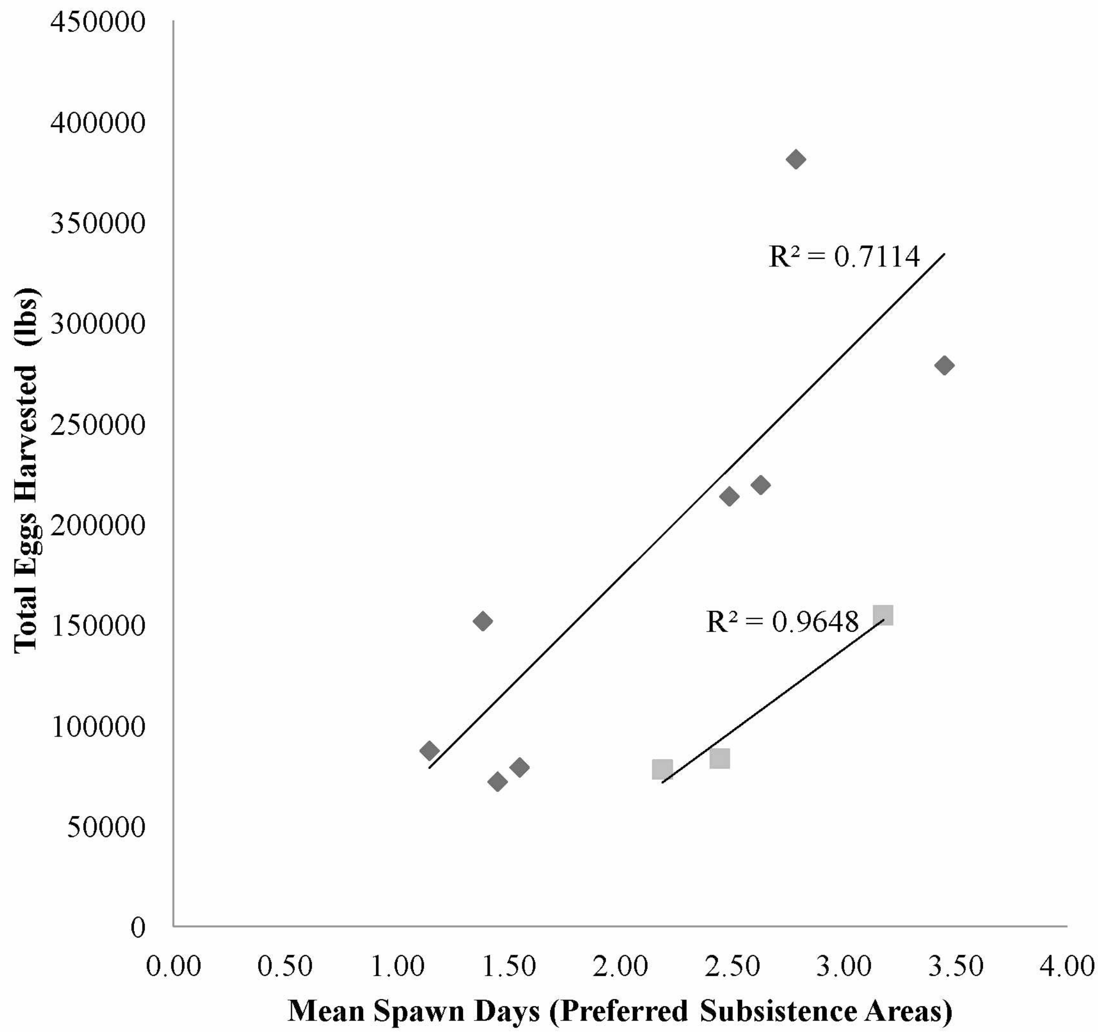

Fig. 3.8 Average number of spawning days in preferred subsistence areas vs. total annual subsistence harvest (lbs). Trend lines are broken out into two time periods, 2002-2009 and 2010 to 2012.

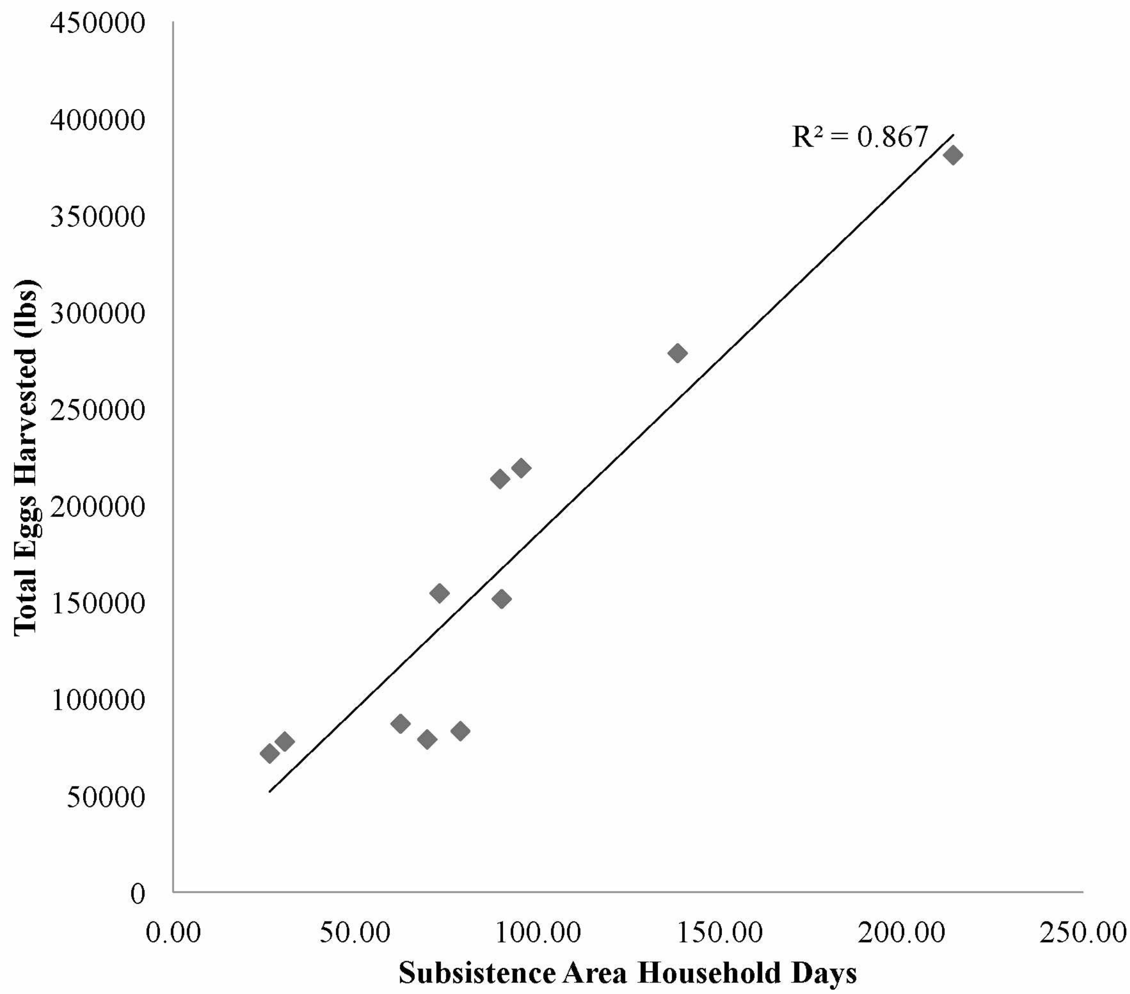

Fig. 3.9 Linear model showing the relationship between household days in subsistence areas (number of participating households x mean spawn days) and the total amount of eggs harvested in pounds during the study period.

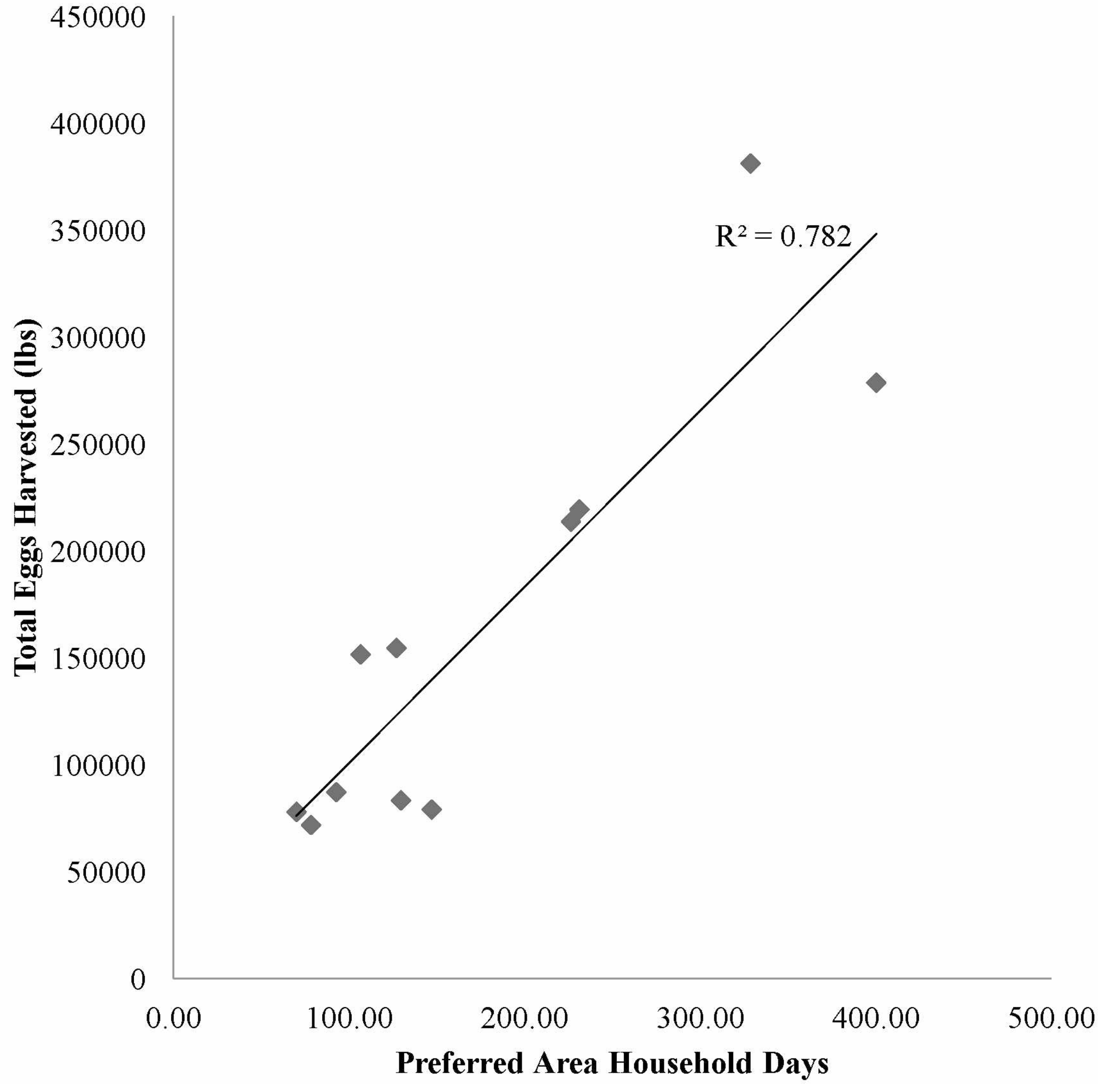

Fig. 3.10 Linear model showing the relationship between household days in subsistence areas (number of participating households x mean spawn days) and the total amount of eggs harvested in pounds during the study period.

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General Discussion

Overview

From its onset, there have been three overall research objectives for this project. The first objective was to identify, through Traditional Ecological Knowledge (TEK), social and ecological attributes that drive subsistence harvest effort with a particular interest in the role of geography. The second objective was to map and analyze the social-ecological system (SES) that includes pacific herring (*clupea palasii*) and subsistence harvest. These two steps were done to support the final objective of situating recent policy debates and conflicts over herring management within a spatial resilience theoretical framework.

The purpose behind analyzing fisheries through a social ecological system (SES) lens stems largely from the old saying that "fisheries management is people management". Social-ecological systems challenge the traditional methods for managing fisheries, which generally rely on modeling single species stocks through time. This approach treats fish, in this case herring, as an isolated and predictable population from which a surplus can be sustainably harvested. SES theory provides a framework that places the biomass of fish into a broader and more holistic context that incorporates the role of landscape ecology and human interaction in shaping the fish population, and vice versa. This is important because small scale fisheries founded on cultural precepts rarely fit neatly into traditional fisheries science molds and models. Social science methods in the policy arena are often viewed with extreme skepticism and cultural views dismissed as "anecdotal evidence". The work contained within this thesis has been an attempt to move cultural values and TEK out of the realm of "anecdote" and prove their usefulness in mapping and measuring where people harvest and why they value areas as much as they do. This isn't done to simplify or boil down the richness of context contained within TEK. It's simply an effort to make this type of information more "digestible" to resource managers and policy-makers, who rarely have a background in anthropology or sociology.

Discussion

Defining the System

The system of interest for this study was Sitka Sound and the subsistence herring fishery that occurs there. Sitka sound is home to one of the state's last large viable stocks of pacific herring (Hebert 2011). It's also home to a sizeable Alaska Native population (~1500 or 17 percent of the local population) (Census.gov). By using a SES framework, the purpose of the project has been to analyze trends in subsistence harvest patterns, the role of space in subsistence activities, why needs are not being met, and how changes to the system contribute to conflicts over space in the policy arena.

From an ecological perspective, the SES includes pacific herring, the habitat in which herring spawn, and the areas that are suitable for subsistence harvest. It also includes social actors and institutions such as the commercial seining fleet, ADF&G, Sitka Tribe of Alaska, and the Board of Fisheries. Because this research is focused on subsistence needs, it's important to define the marine landscape in terms useful to subsistence harvest.

Subsistence harvesters have a particular definition of what areas are ideal for making subsistence sets. The major components of this definition are based on availability of and accessibility to eggs as well as various concepts of egg quality. Spatial analysis shows that there is a strong link between socially constructed harvest areas and ecological variables such as spawn day clustering, shore type, and protection from waves. Herring do not spawn uniformly throughout the Sound, but generally concentrate in certain areas. When these areas overlap with subsistence areas it creates prime opportunity for subsistence harvesting to take place.

There are several actors that contribute to the social component of the system. There is the commercial fishing fleet, which is given the opportunity to harvest a portion of the biomass prior to its arrival to the spawning areas. This may potentially scatter the stock, disrupting access to spawning areas and interrupting the subsistence fishery, but more research is needed to determine if such a relationship exists and to what extent. ADF&G is tasked with managing the commercial fishing effort, as well as with providing reasonable opportunity for subsistence fishing to occur. They do this through a fisheries management plan, modeling of the biomass, and in season management of the commercial fishery. ADF&G also documents information regarding the success of the subsistence fishery through the Division of Subsistence. The Board of Fish sets regulations once every three years that guide long term management of both fisheries. Sitka Tribe of Alaska represents the legal concerns of its tribal membership and lobbies for the protection of subsistence rights. Because this is such a complex system with numerous actors representing different objectives and cultural values, a simplified single species management plan can be problematic, especially under the state's constitutional authority to promote use for all Alaskans.

Resilience Theory

Once the system is defined and the stage is set, the next step is to analyze the systems properties to understand why needs are not being met. For this we turn to resilience theory. Gunderson and Holling (in Carpenter et al. 2001) define resilience as "the capacity of a system to undergo disturbance and maintain its function and controls." Therefore, resilience theory is a social ecological systems theory that attempts to explain how a particular system varies through time, what causes changes in the system state, and how changes in the state of the system impacts livelihoods. Most importantly, Carpenter (2001) emphasizes that resilience research begins by "clearly defining resilience in terms *of* what *to* what". For subsistence herring in Sitka Sound and the purpose of this thesis, the "of what" refers to subsistence harvest outcomes, or the ability to meet subsistence needs. The "to what" portion of the equation refers to the availability of and accessibility to herring spawn. Narrowing down even further, resilience can be analyzed spatially, incorporating the role of spatial variation in understanding SES resilience (Cumming 2011). This can include factors such as the spatial distribution of people and/or resources and how it influences the system state and outcomes. By synthesizing Gunderson and Hollings definition with the inclusion of the marine space, spatial resilience for this project can then be defined as the role that key geographic features of Sitka Sound play in providing opportunity for subsistence herring egg harvest, given fluctuations in herring abundance, the distribution of spawn deposition, and social drivers. Using this approach should address the need to better understand what factors are contributing or inhibiting the degree to which subsistence needs are being met. The inclusion of the spatial component is important since actions taken by the 2012 Alaska Board of Fish (BOF) to address subsistence concerns involved the creation of a "subsistence only" zone (SOZ). This zone excludes commercial fishing effort, creating a safe haven from active fishing pressures, presumably allowing for a more natural spawn in a key subsistence area.

Policy Application

Marine Protected Areas (MPA's) are often seen as a useful tool for conservation. Generally the goals for an MPA's are centered on environmental conservation, yet in the case of the SOZ in Sitka, the concern is one of cultural preservation. In order for an MPA to be successful, it must adhere to two basic standards. It must be representative and it must be persistent (Salomon et al. 2006). In ecological terms, it must represent the full extent of biodiversity and that extent must also support long term sustainability. From a purely cultural perspective, it must be representative of cultural needs and provide a reasonable extent necessary for the persistence of cultural practices. While the creation of a subsistence only zone (SOZ) was intended as a way of protecting access and opportunity, there is a danger in drawing and defining boundaries across the marine landscape, especially when they fail to meet such criteria. Subsistence harvesters are already limited in terms of spatial resilience. Only a handful of areas in Sitka Sound consistently meet the criteria for being suitable for harvest. By codifying certain areas as "subsistence only", there is a risk in creating the perception that all other areas outside of this are thus “non subsistence”, or reserved for commercial harvest. This could “box in” subsistence opportunity and further reduce resilience.

While a SOZ was created, it was a much smaller area than what was originally proposed by a local high harvester. It also failed to include a few key areas, namely the north end of Middle Island and the adjacent north end of Crow Pass. It also ignored Gavanski Island, North Halibut Point Road, and the open waters in between. The open water area was the most highly contentious part of the original proposal, because the commercial fleet uses that area for staging and commercial fishing does occur there on occasion. The main justification for including the open water area was that it would provide a safe haven for pre spawn herring to congregate away from commercial fishing pressures so that a more “natural” spawn could occur. Unfortunately there is very little published data to substantiate whether or not commercial fishing stresses or scatters herring causing what is locally known as a “false spawn”. False spawn is when males rush to a beach and release milt where no eggs or females are present. Neither the industry nor ADF&G supported the inclusion of the open water area because it was seen as being too restrictive on the management regime. Working with the BOF, Agency staff and industry reps worked to create a “compromise” plan, which is the plan the Board passed. Sitka Tribe, the federally recognized tribal government in Sitka, did not support the final plan.

Cultural MPA’s are not unusual in Sitka Sound. In 1997, the BOF assembled a community task force to create the Sitka Sound Local Area Management Plan (LAMP) as a response to increased charter fishing pressures. The purpose of the LAMP was to create a safe haven within Sitka Sound for personal use, subsistence, and non-guided sport anglers who lacked the equipment to fish outside of the Sound (Witherall and Woodby, 2005). The LAMP and the process involved in drafting it have been hailed as a successful example of "public policy [assessing] the assorted values of society and [attending] them in a manner that… results in more benefits than undesirable consequences" (Springer 2006). Why a similar task force was not drafted in this case to consider a more community centered solution is unclear. The SOZ has come up in previous Board cycles; it's possible that the SOZ was only passed as an act of appeasement. Unfortunately, drawing boundaries and allocating use areas can have substantial long term consequences. This is why it is important that MPA's be constructed in a way that is both representative and persistent. Engaging more with subsistence harvesters, incorporating their knowledge and values in the decision process, is a major step when dealing with culturally significant fisheries.

MPA's are not the only solution. Taking better account of spatial distributions of herring, the impacts of commercial fishing effort on spawn, and developing better understandings of extremely abnormal years such as 2008 could help develop in season management tools. These tools could be used to direct commercial effort in a way that protects spawn around subsistence areas.

Industry affiliates have in recent years sponsored larger "community vessels" to come in, make sets, and distribute eggs locally as well as to other remote communities in southeast Alaska. While this is an effective means for harvesting and distributing eggs, especially to rural Alaska, it has proven controversial locally. Mass harvesting eggs on a large vessel removes the cultural importance associated with subsistence activity. To paraphrase one local participant, the herring fishery is the first big subsistence activity of a new year, it’s a sign that spring has arrived in Sitka. It’s a chance to dust off the winter cobwebs and enjoy some time on the water. Simply providing massive quantities of eggs does little to promote the resilience of the cultural and social benefits that come from subsistence harvesting. To ensure the cultural future of subsistence activities requires more than just the providing of physical needs in a given year, it requires reinvigorating the cultural tradition and practice that these fisheries support. Efforts to protect areas from commercial fishing pressure are by and large a social response to declines in participation, opportunity, and the meeting of needs. This is not just in terms of pounds of eggs distributed, but in the cultural language that these fisheries are tied to.

Conclusions

Using spatial resilience theory and a SES approach creates a more holistic image of the distribution of herring and herring spawn (the ecological) and subsistence harvester and harvest areas (the social) and how changes to that relationship alter the outcome in the subsistence herring roe fishery. This is important because when subsistence needs are not consistently met those concerns are brought to the policy arena and can influence long term management decisions. Those decisions need to incorporate both social and ecological elements in order to accurately address issues and concerns to the benefit of all Alaskans.

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Appendix A: IRB Exemption

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January 2, 2013

To:	Joshua Greenberg, PhD Principal Investigator
From:	University of Alaska Fairbanks IRB
Re:	[401799-2] Spatial Resilience and the Incorporation of Traditional Ecological Knowledge in Understanding Subsistence Use of Sitka Sound Herring

Thank you for submitting the Amendment/Modification referenced below. The submission was handled by Exempt Review. The Office of Research Integrity has determined that the proposed research qualifies for exemption from the requirements of 45 CFR 46. This exemption does not waive the researchers' responsibility to adhere to basic ethical principles for the responsible conduct of research and discipline specific professional standards.

Title:	Spatial Resilience and the Incorporation of Traditional Ecological Knowledge in Understanding Subsistence Use of Sitka Sound Herring
Received:	December 20, 2012
Exemption Category:	7
Effective Date:	January 2, 2013

This action is included on the January 17, 2013 IRB Agenda.

Prior to making substantive changes to the scope of research, research tools, or personnel involved on the project, please contact the Office of Research Integrity to determine whether or not additional review is required. Additional review is not required for small editorial changes to improve the clarity or readability of the research tools or other documents.